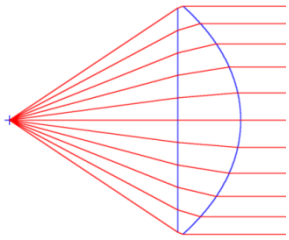
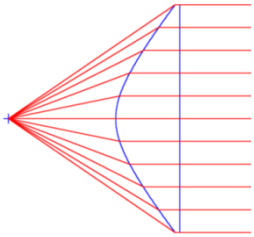
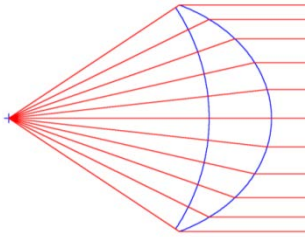
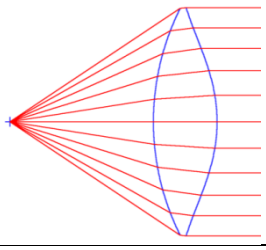
9-2.1 CHAMP BOR-MoM Analysis of Zoned Lenses

Section 9-2 discusses zoned lens by using a geometric analysis with ray tracing to determine aperture distribution combined with spillover of the dead zones. These dead zones can be located in either the portion of the feed pattern not diffracted to the aperture or portion of the aperture not excited. Section 9-2 uses aperture taper loss to account for the unexcited aperture portions. The feed dead-zones can be considered spillover loss because that portion of the feed power is scattered in useless directions and adds to the sidelobes. CHAMP (TICRA) analysis of feed horns can include external dielectric scatterers (lenses) in its BOR-MoM analysis that interacts with the modal expansion in the horn. Each mode in the horn aperture interacts with the BOR-MoM solved separately mode by mode. This analysis not only computes the final pattern, but the reaction of the scatterers on the horn input impedance.

The general two-surface lenses of Section 9-3 are used for this analysis. The zoning removes material either from the feed or radiation side of the lens along the ray path through the lens. A third approach is to remove material from both sides where the sum is the same as on either side alone. Table 1 illustrates the eighteen types of zoning considered for 20λ diameter lenses for a 2.55 dielectric constant. The combined zoning shows each side having half the zoning, but the two sides could be different. The flat lenses can be made from thinner blanks which reduces cost and in some cases, thicker blanks are not available.

Table 1. Lens Zoning for 20λ diameter 2.55 Dielectric Lens

Lens	No Zoning	Feed Side Zoning	Radiation Side Zoning	Combined Zoning
Flat Feed Side Surface				
Flat Radiation Side Surface				
Concave Sphere Feed Side				
Convex Sphere Feed Side				

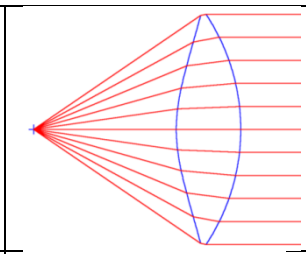
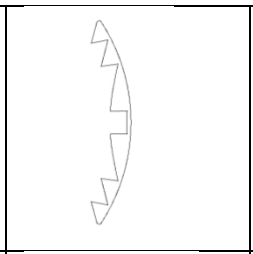
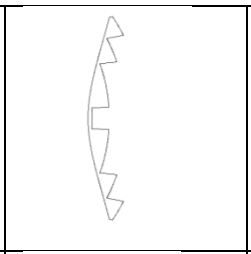
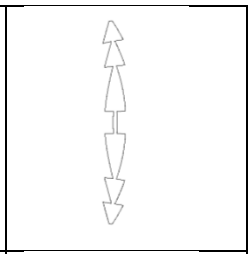
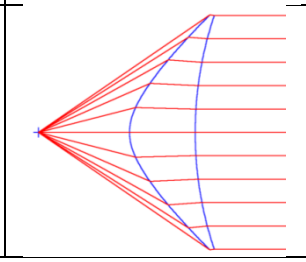
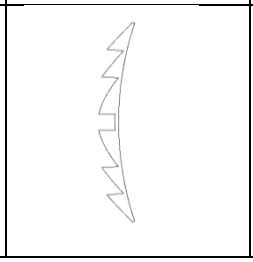
Convex Sphere Radiation Side				
Concave Sphere Radiation Side				

Table 2. Efficiency of 20λ diameter Zoned Lenses (Spillover and Taper Loss) 66° 10-dB Beamwidth Feed

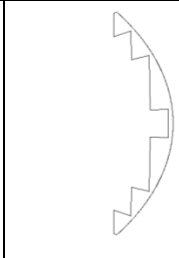
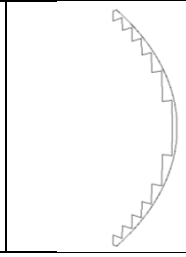
Lens	No Zoning	Feed Side Zoning	Radiation Side Zoning	Combined Zoning
Flat Feed Side Surface	-1.03 dB	-1.96	-2.44	-2.37
Flat Radiation Side Surface	-2.47	-3.73	-3.49	-3.62
Concave Sphere Feed Side	-0.63	-1.74	-2.44	-2.18
Convex Sphere Feed Side	-1.51	-2.58	-2.73	-3.19
Convex Sphere Radiation Side	-1.49	-2.44	-2.48	-2.82
Concave Sphere Radiation Side	-3.68	-7.58	-4.80	-6.16

Table 3. Efficiency of Flat Feed Side Surface Zoned Lenses using 66° 10-dB Beamwidth Feed

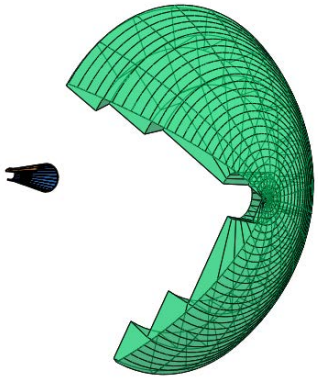
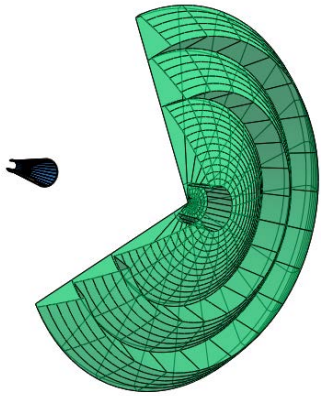
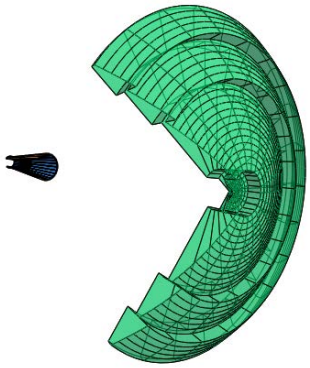
Diameter	No Zoning	Feed Side Zoning	Radiation Side Zoning	Combined Zoning
20λ	-1.03 dB	-1.96	-2.44	-2.37
40λ	-1.24	-2.27	-3.14	-2.87

Larger diameter lenses have more zones as shown in Table 4 where the 20λ diameter lens has 3 zones while the 40λ diameter lens requires 6 zones. Notice that the efficiency of the lens decreases as the diameter increases because greater area is eliminated from the aperture of the lens.

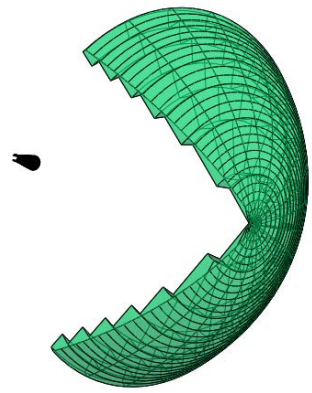
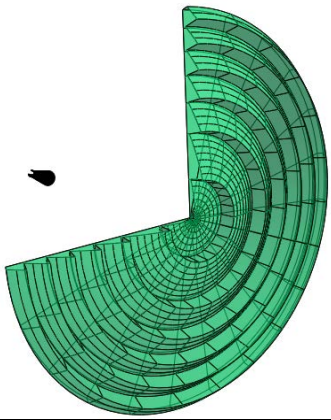
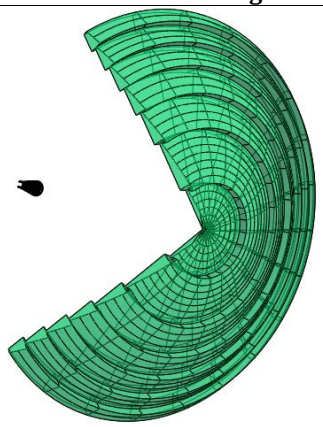
Table 4. Flat Feed Side Surface Zoned Lenses 2.55 Dielectric Lens

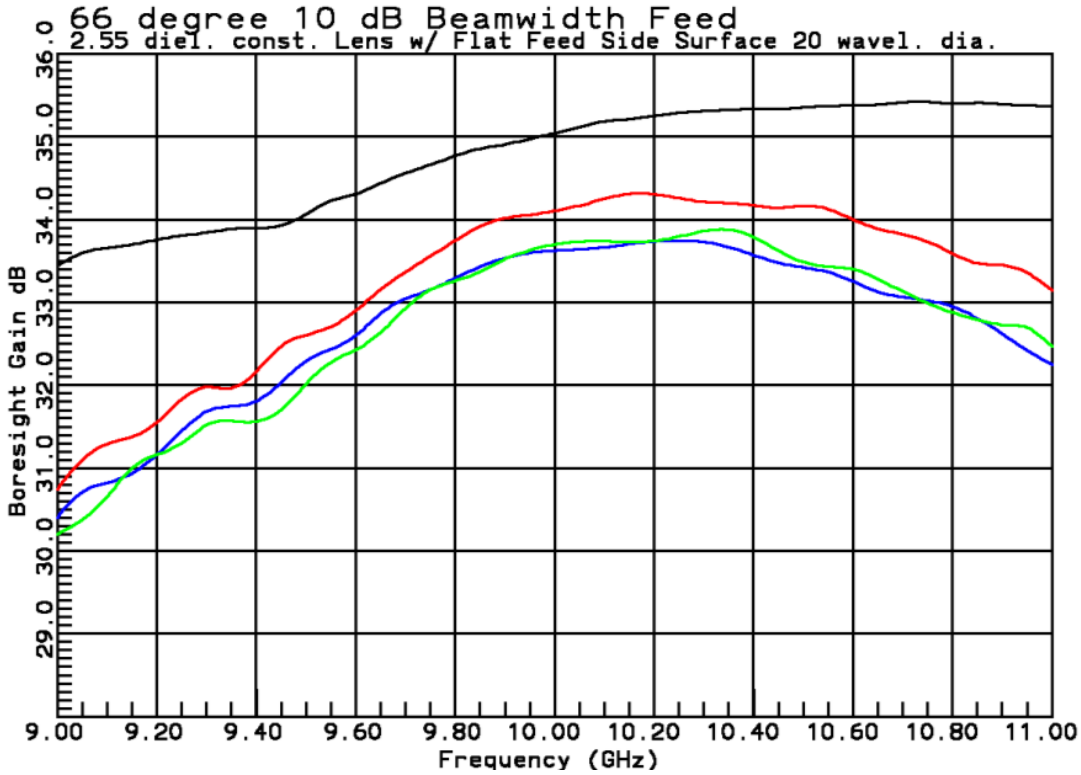
Diameter	Feed Side Zoning	Radiation Side Zoning	Combined Zoning
20λ			
40λ			

Flat Feed Side Surface 20λ diameter

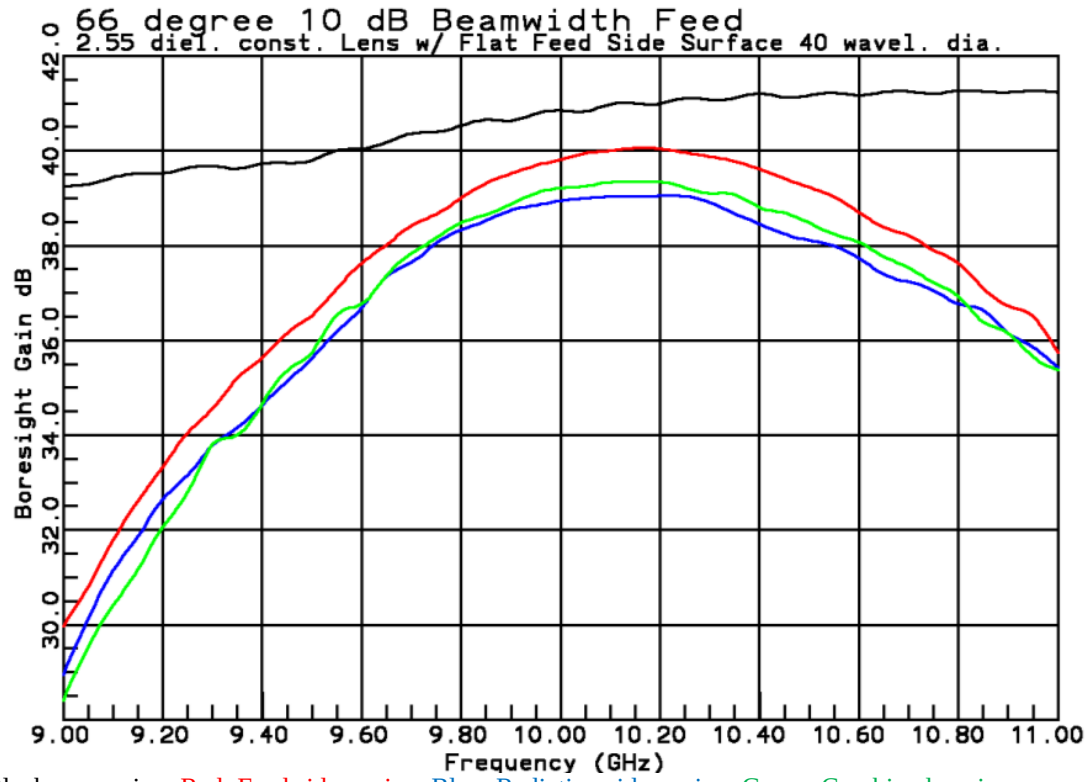
Feed Side Zoning	Radiation Side Zoning	Combined Zoning
		

Flat Feed Side Surface 40λ diameter

Feed Side Zoning	Radiation Side Zoning	Combined Zoning
		

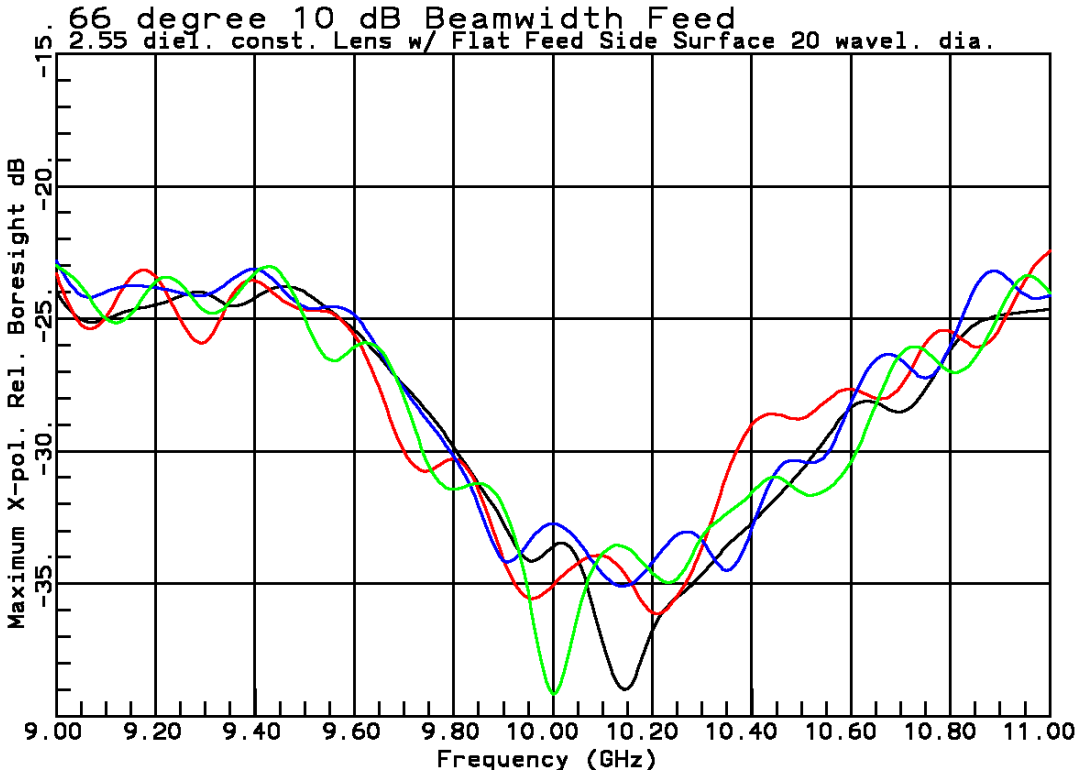


Black: no zoning, Red: Feed side zoning, Blue: Radiation side zoning, Green: Combined zoning

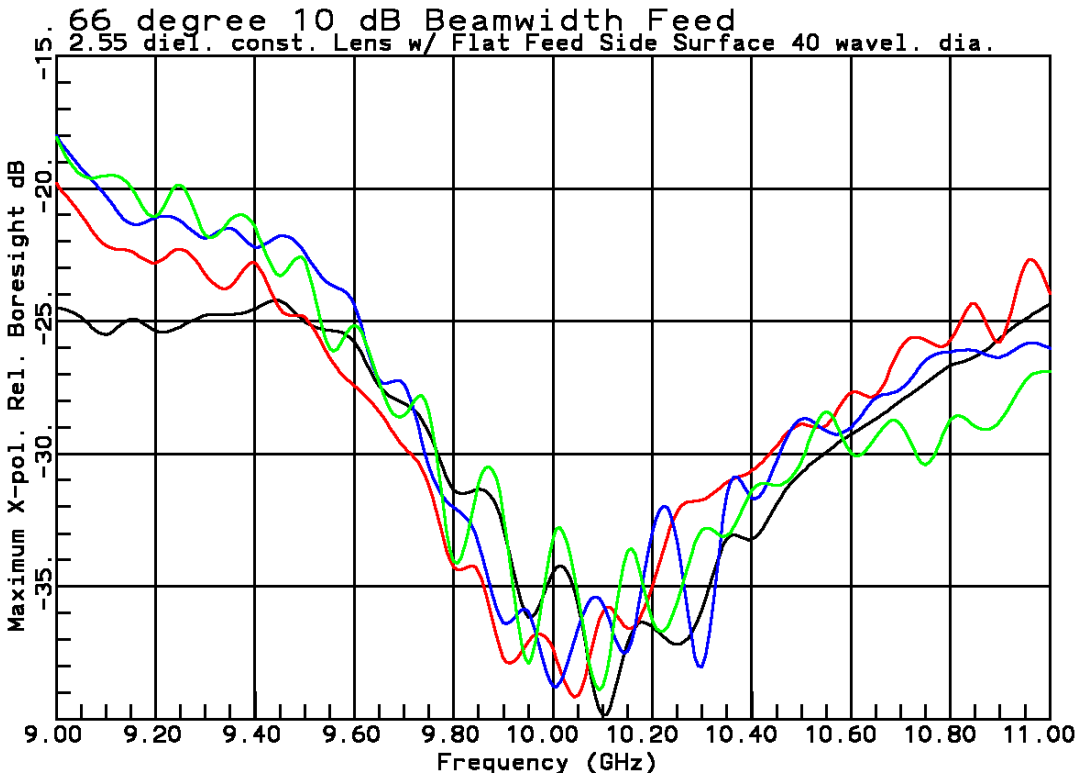


Black: no zoning, Red: Feed side zoning, Blue: Radiation side zoning, Green: Combined zoning

The plot above shows that the lens bandwidth as we increase the diameter and the number of zones. Notice that the vertical scale on the plot above is twice the one above it.

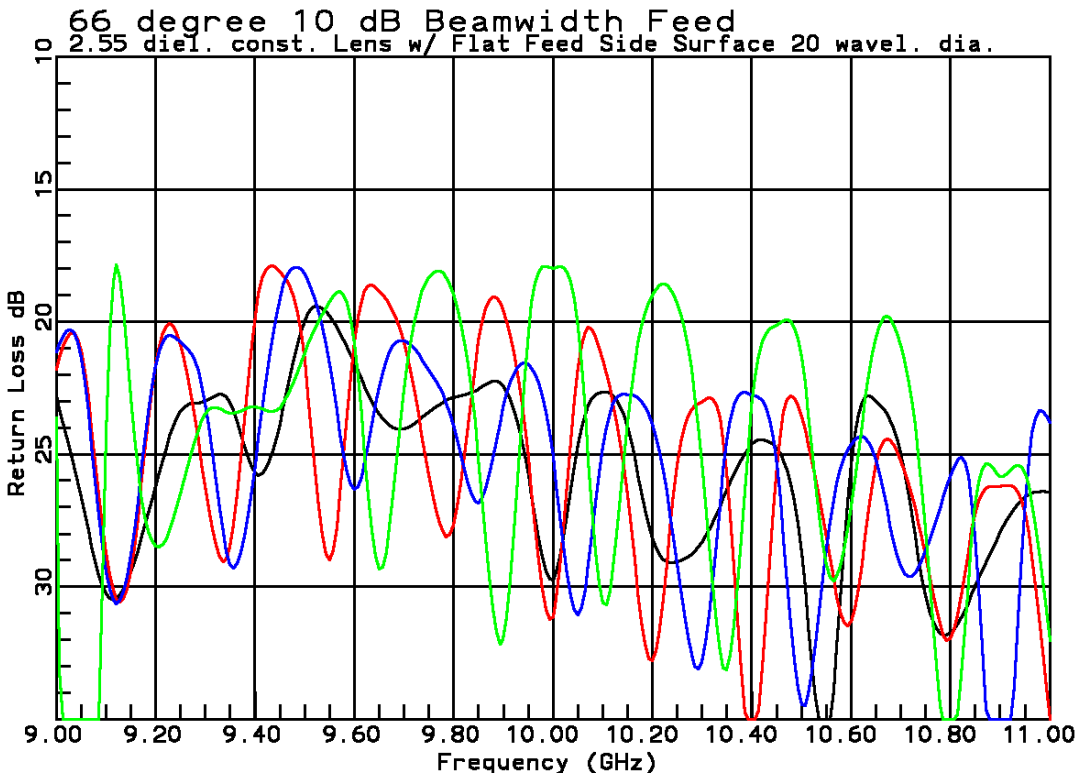


20λ diameter Black: no zoning, Red: Feed side zoning, Blue: Radiation side zoning, Green: Combined zoning

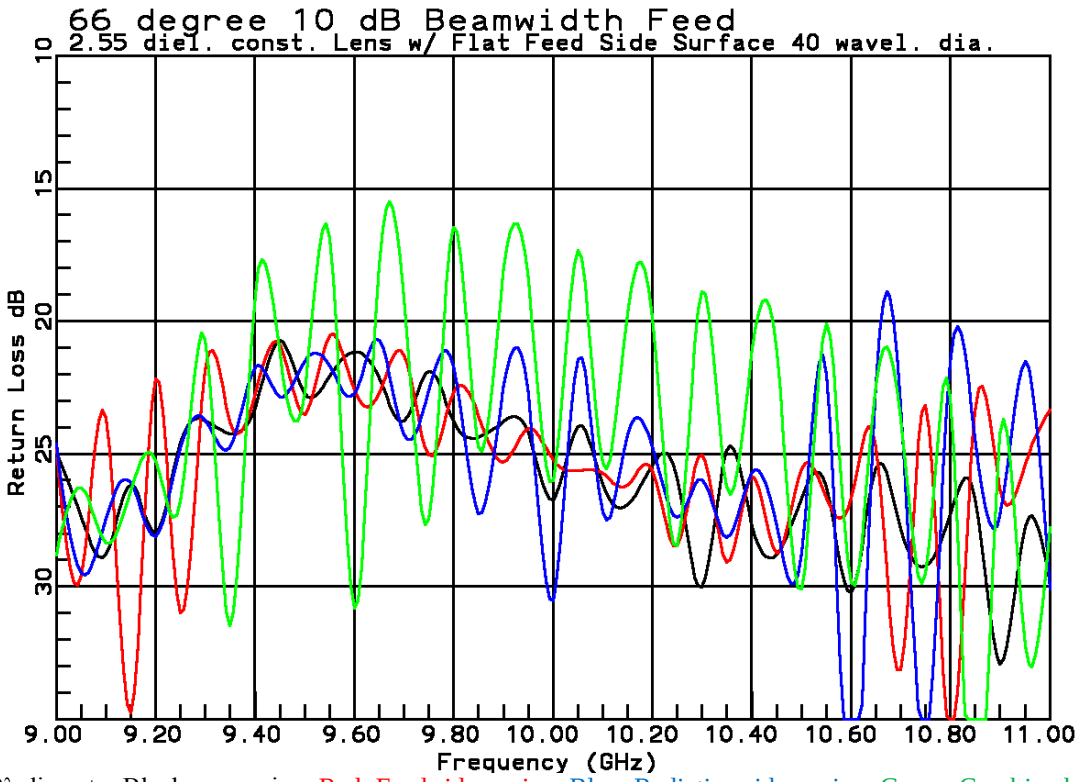


40λ diameter Black: no zoning, Red: Feed side zoning, Blue: Radiation side zoning, Green: Combined zoning

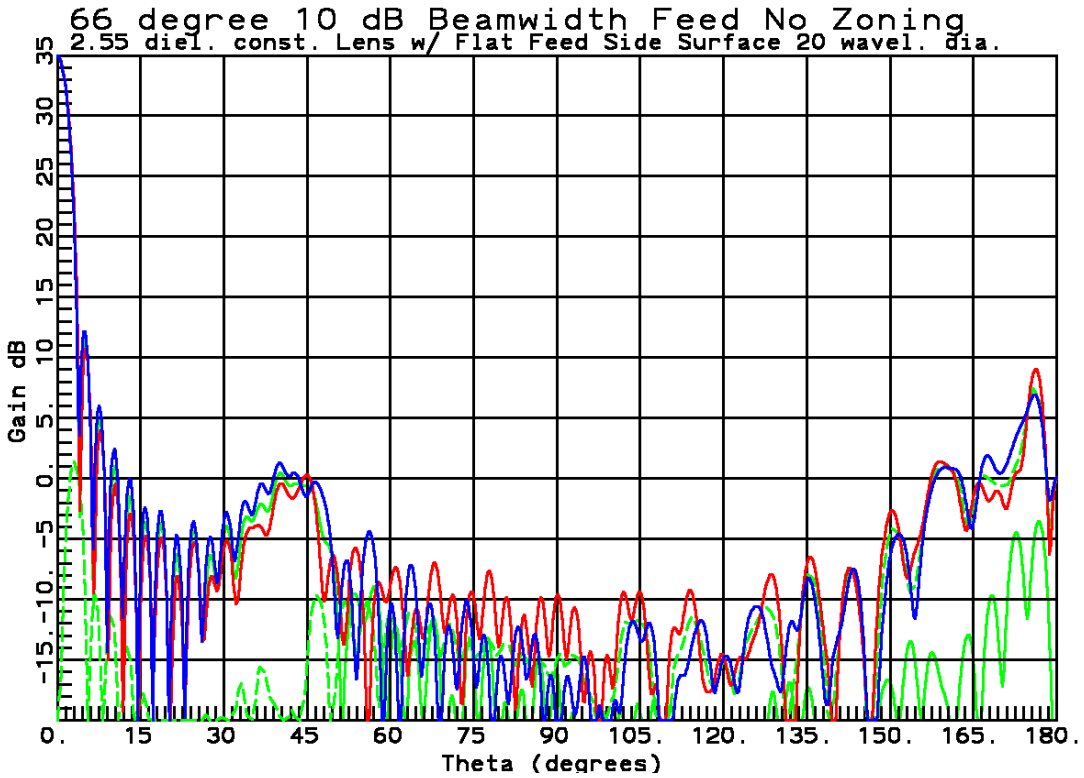
Increasing the lens diameter and the number of zones has little or no effect on maximum cross-polarization relative to bore sight bandwidth.



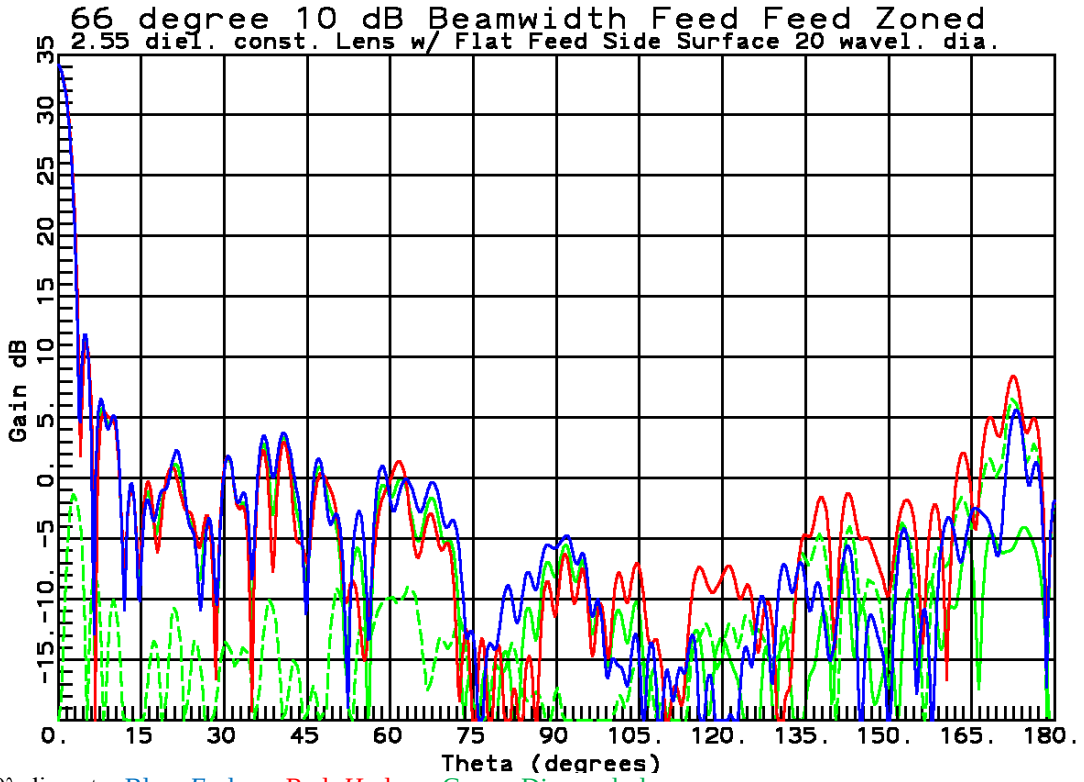
20λ diameter Black: no zoning, Red: Feed side zoning, Blue: Radiation side zoning, Green: Combined zoning



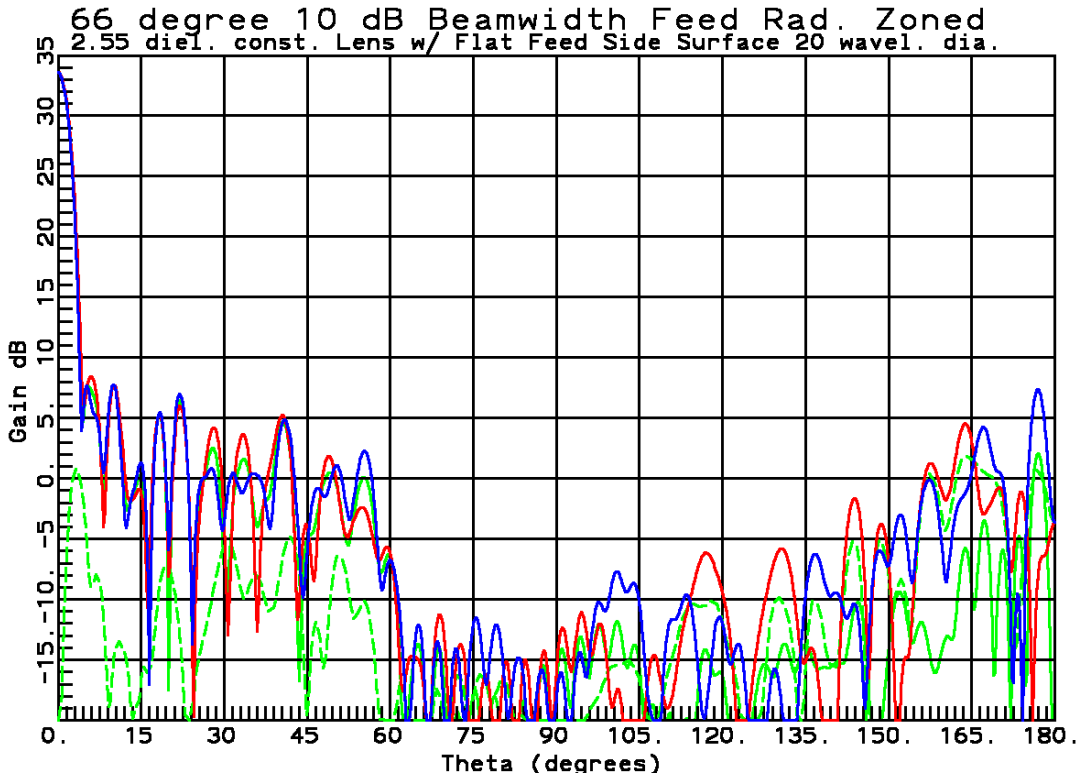
40λ diameter Black: no zoning, Red: Feed side zoning, Blue: Radiation side zoning, Green: Combined zoning



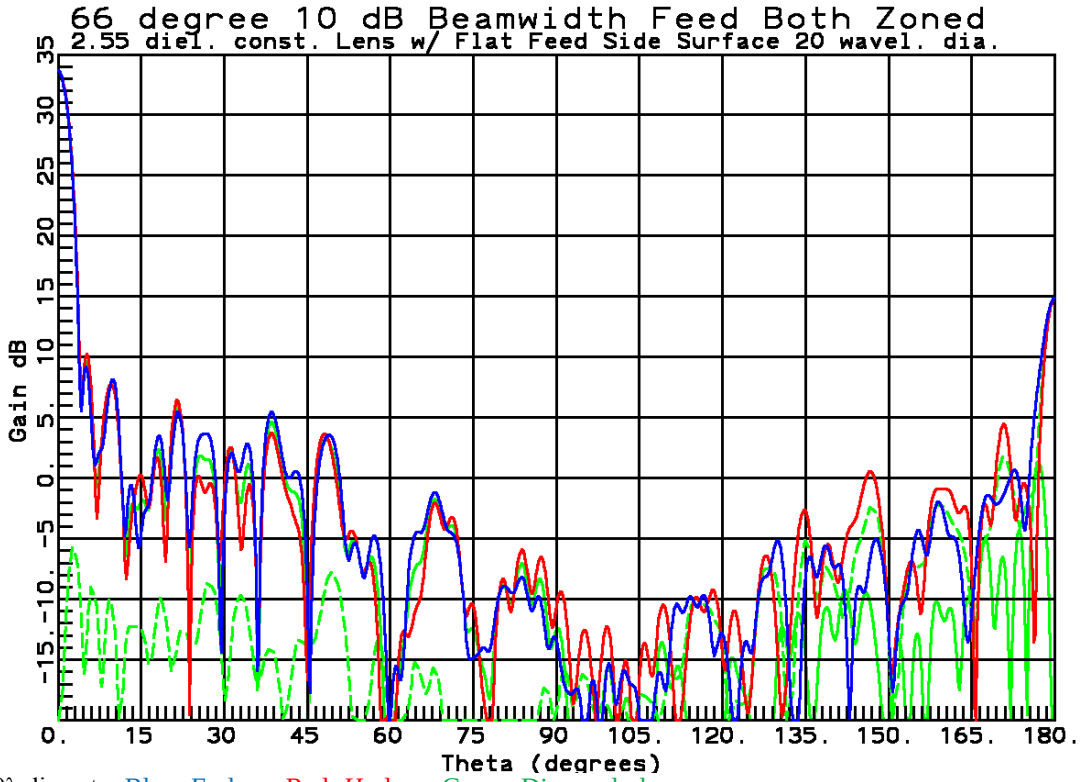
20λ diameter Blue: *E*-plane, Red: *H*-plane, Green: Diagonal plane



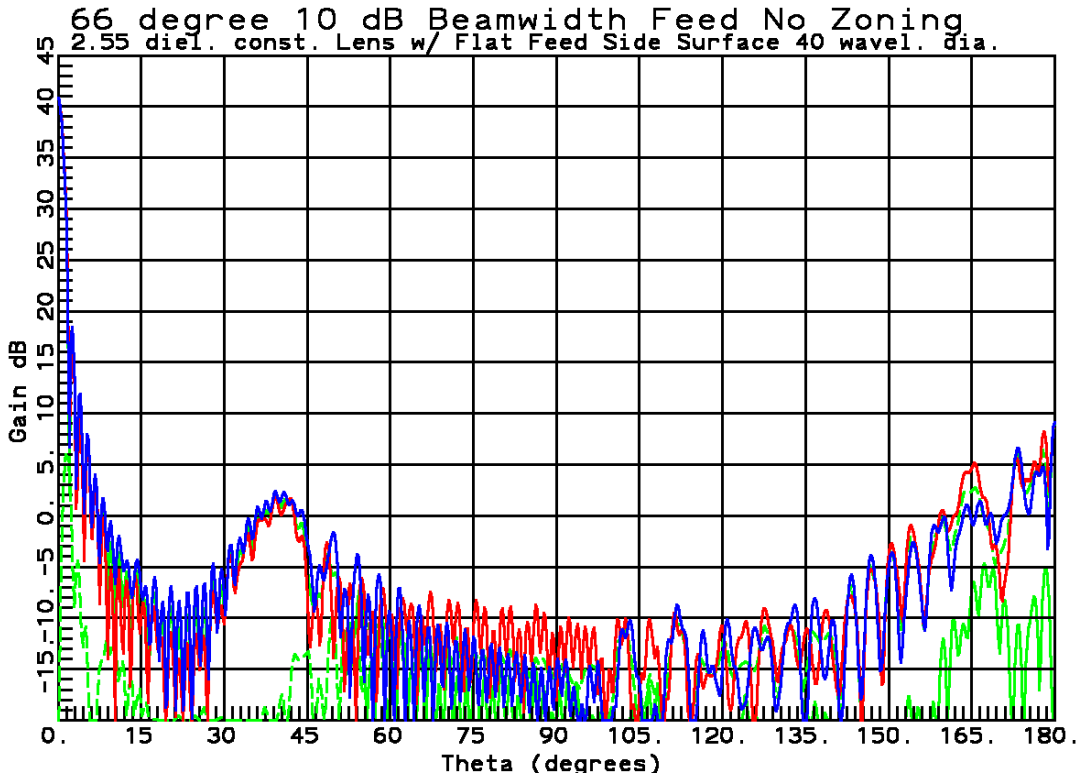
20λ diameter Blue: *E*-plane, Red: *H*-plane, Green: Diagonal plane



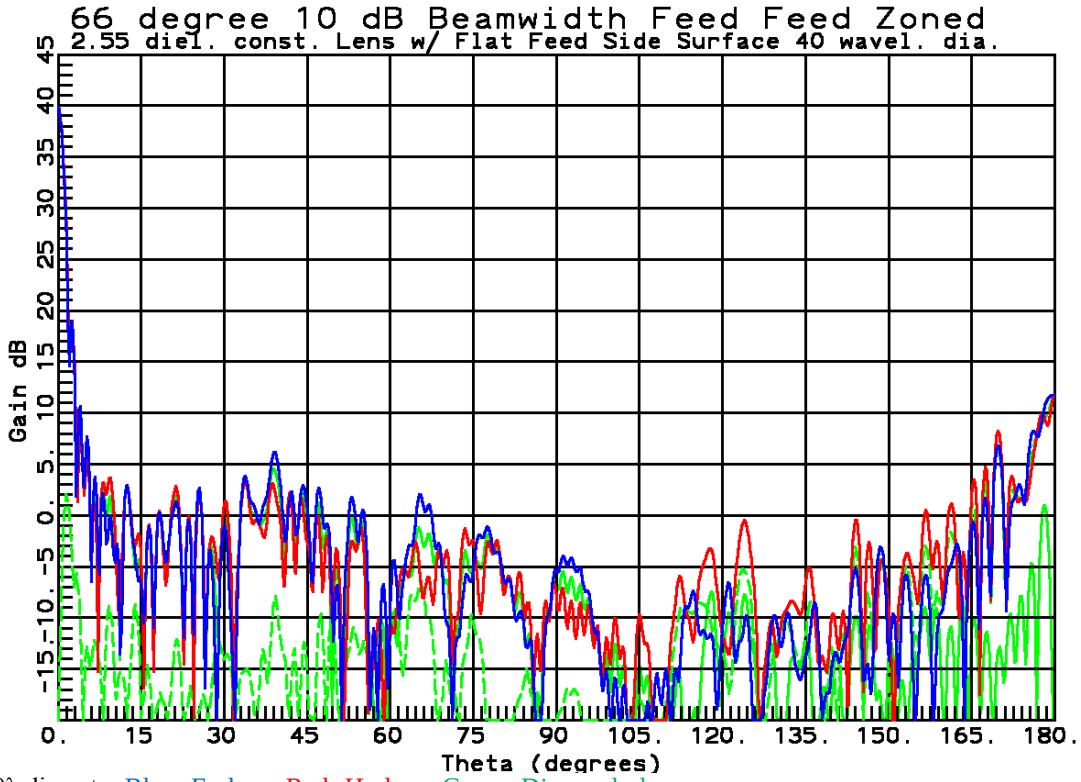
20λ diameter Blue: *E*-plane, Red: *H*-plane, Green: Diagonal plane



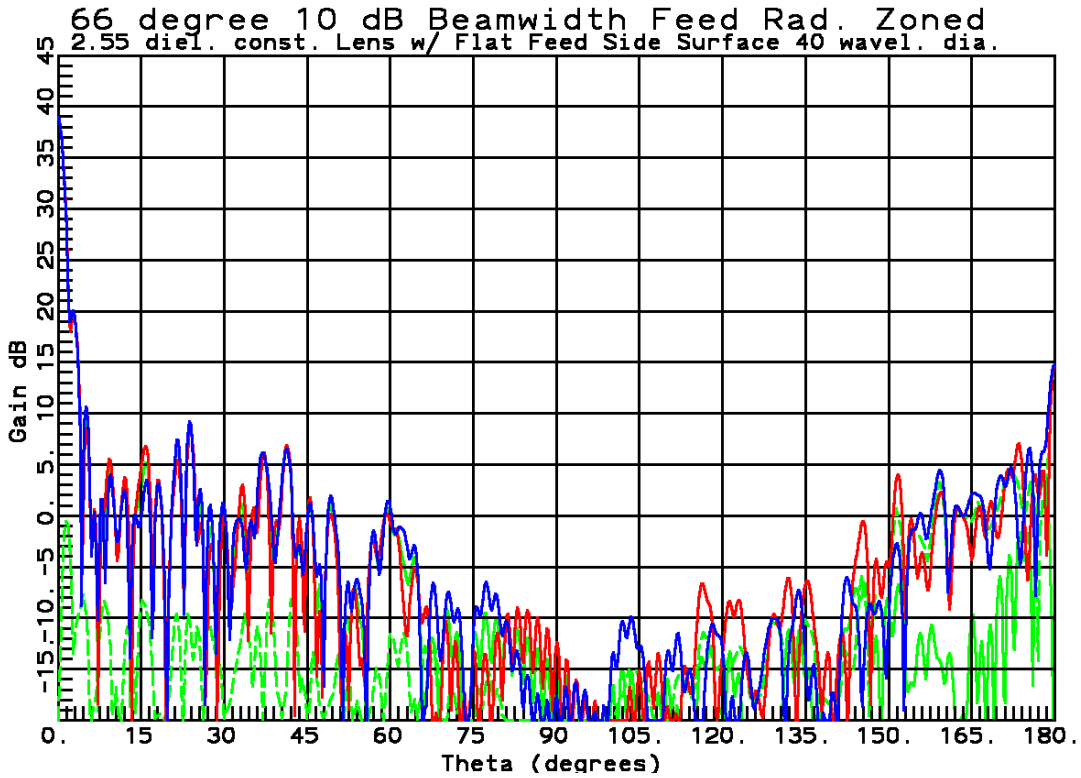
20λ diameter Blue: *E*-plane, Red: *H*-plane, Green: Diagonal plane



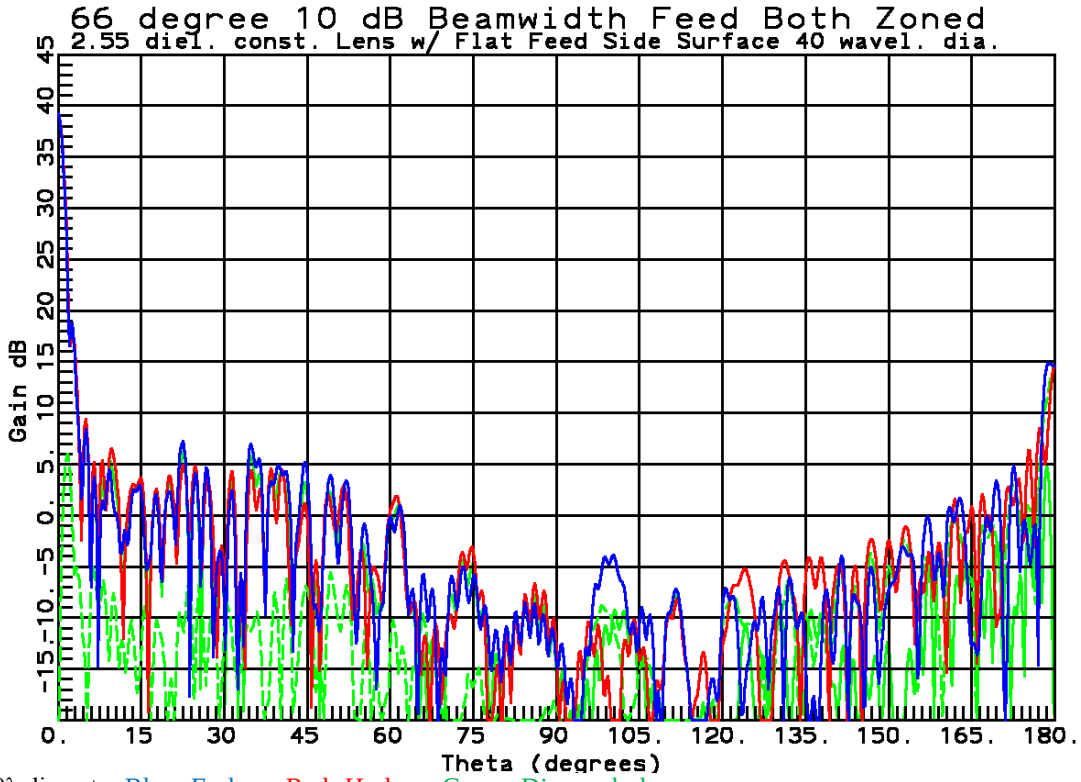
40λ diameter Blue: *E*-plane, Red: *H*-plane, Green: Diagonal plane



40λ diameter Blue: *E*-plane, Red: *H*-plane, Green: Diagonal plane

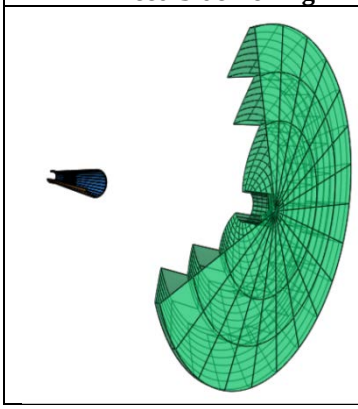
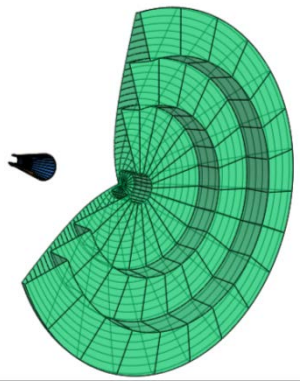
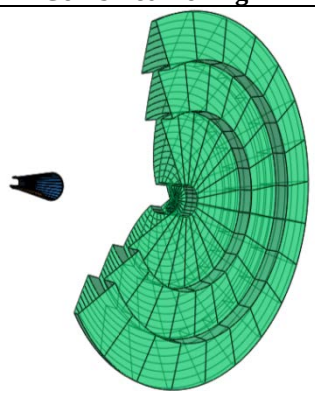


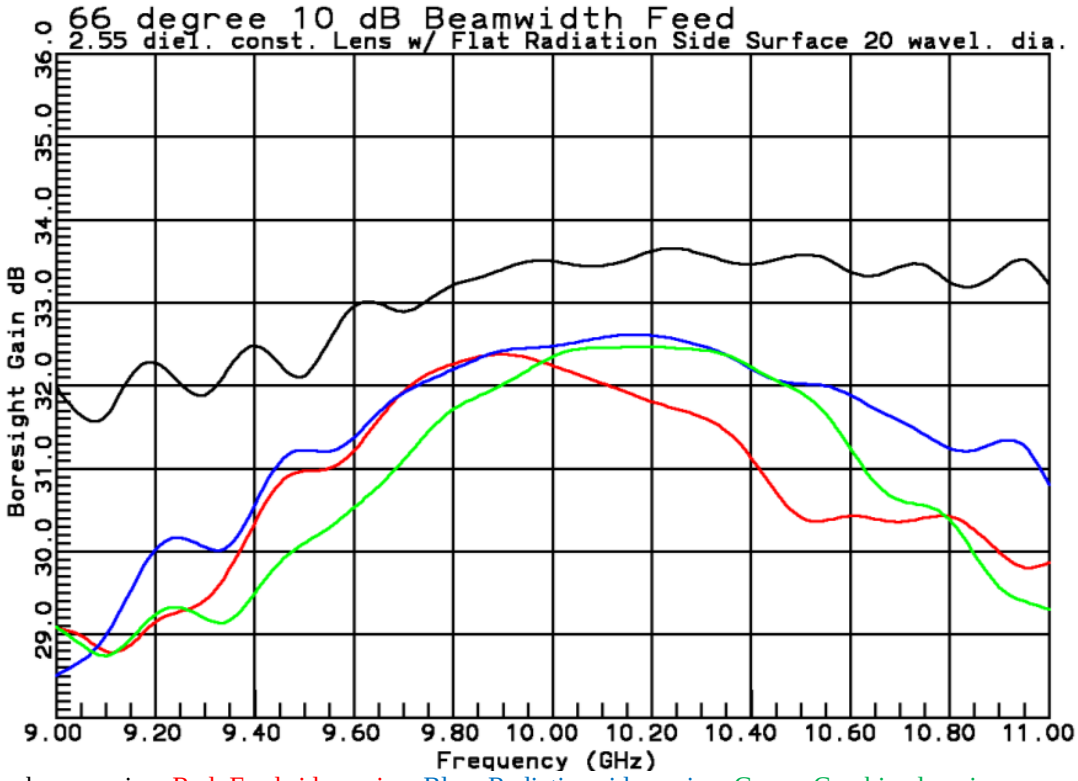
40λ diameter Blue: *E*-plane, Red: *H*-plane, Green: Diagonal plane



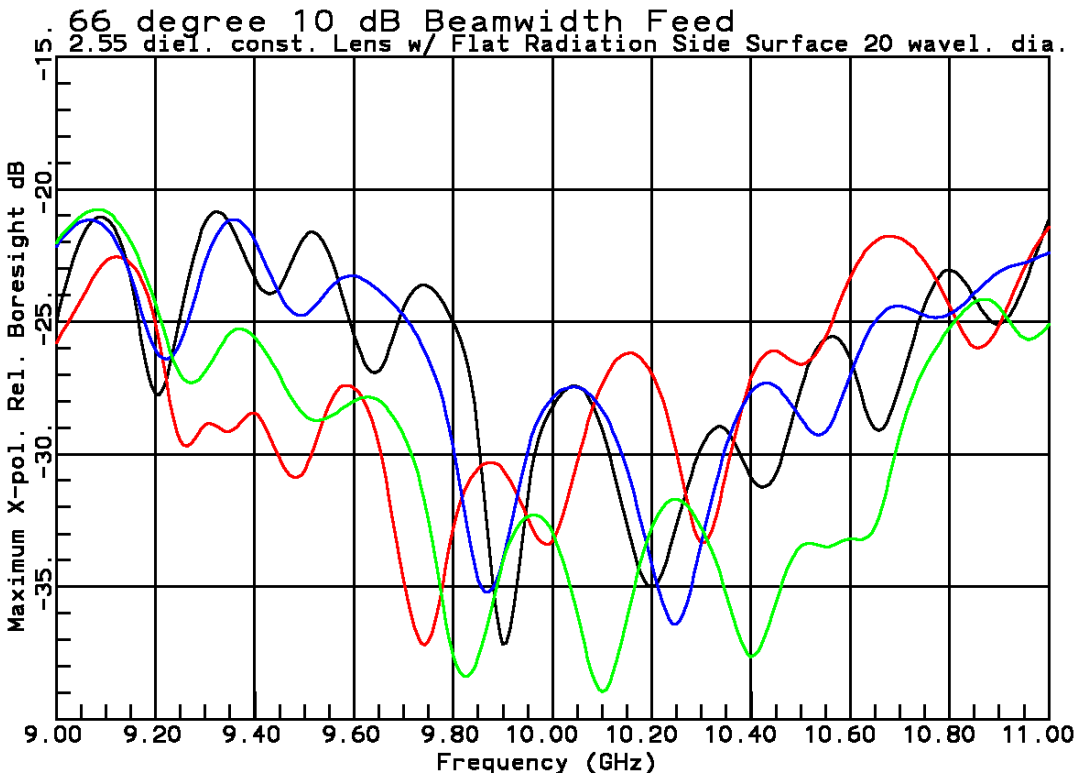
40λ diameter Blue: *E*-plane, Red: *H*-plane, Green: Diagonal plane

Flat Radiation Side Surface

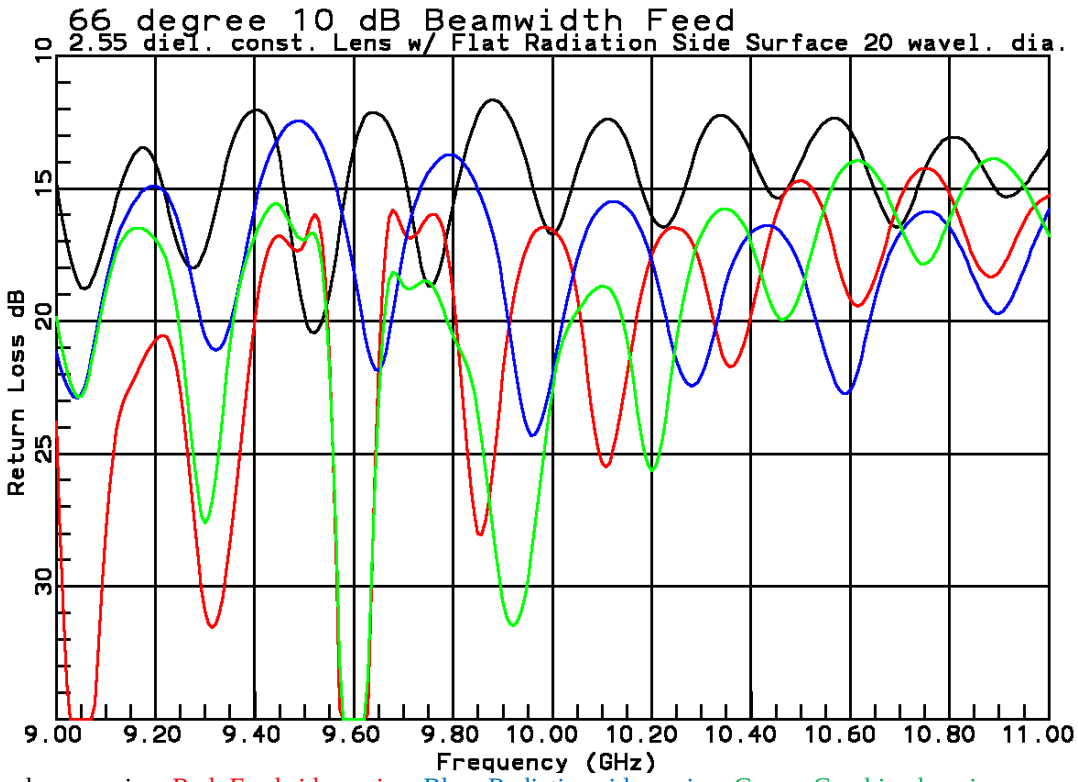
Feed Side Zoning	Radiation Side Zoning	Combined Zoning
		



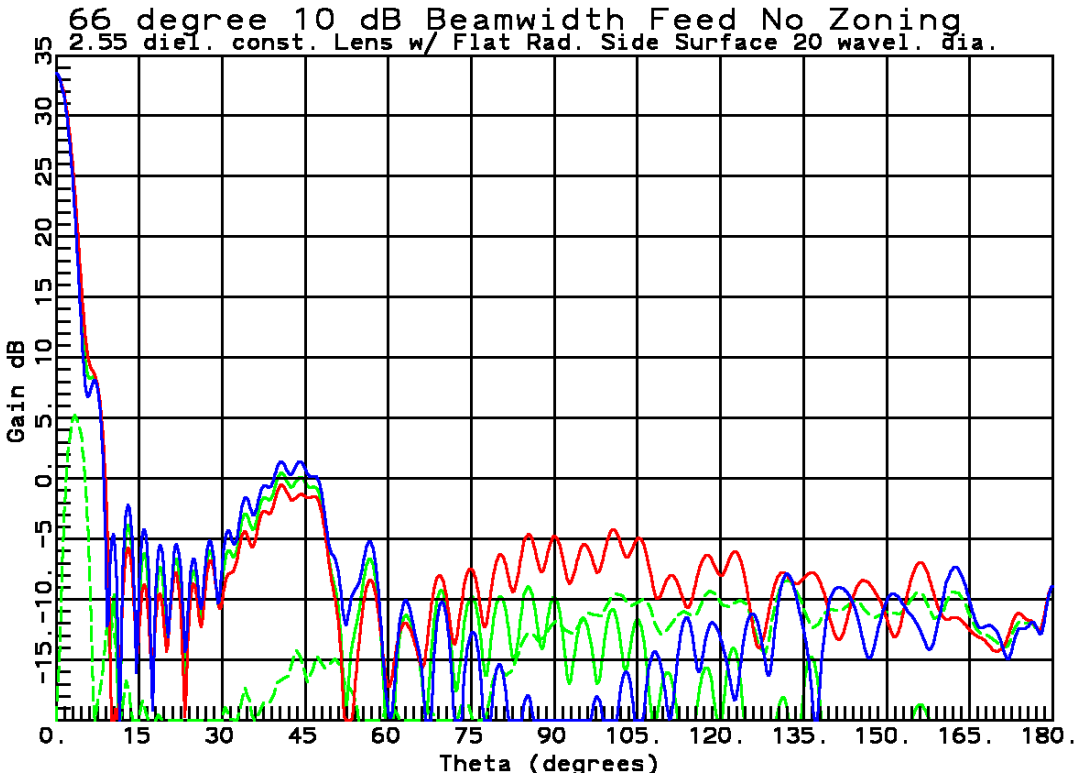
Black: no zoning, Red: Feed side zoning, Blue: Radiation side zoning, Green: Combined zoning



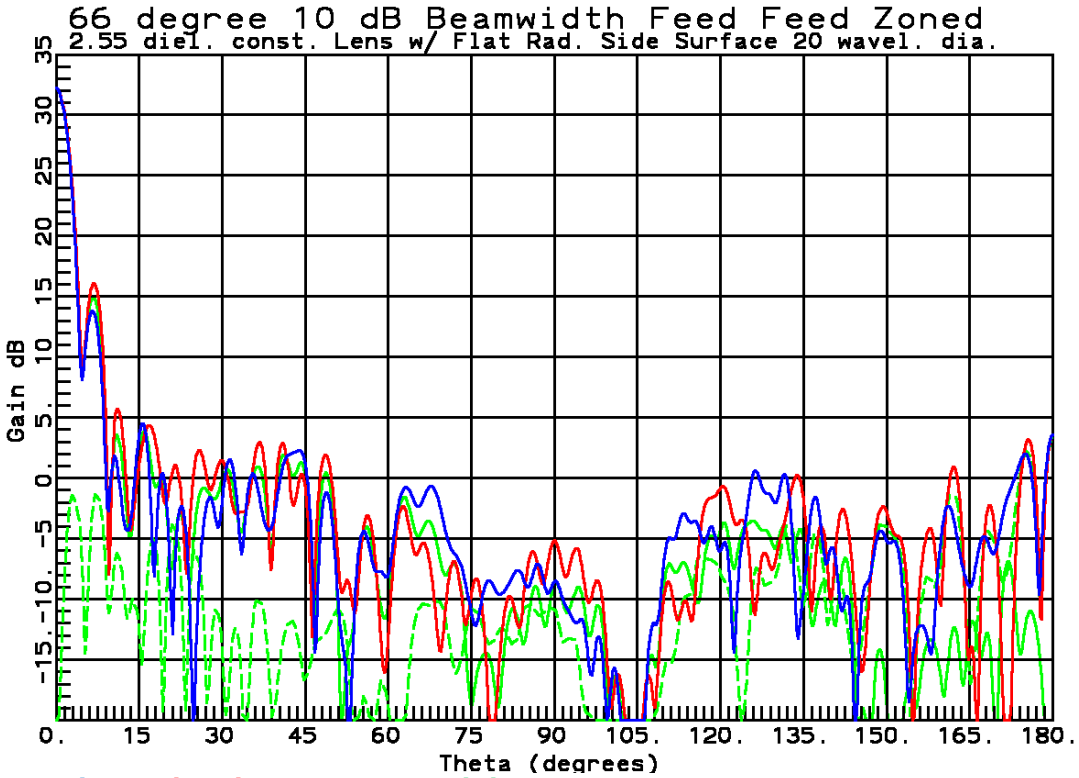
Black: no zoning, Red: Feed side zoning, Blue: Radiation side zoning, Green: Combined zoning



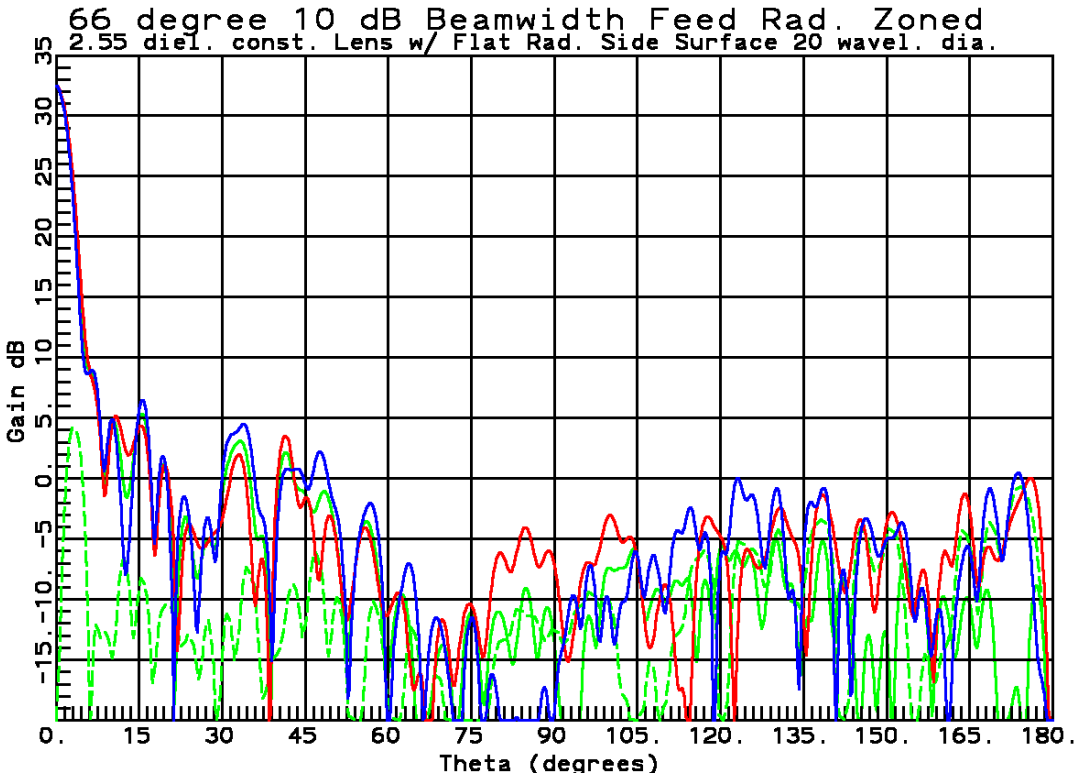
Black: no zoning, Red: Feed side zoning, Blue: Radiation side zoning, Green: Combined zoning



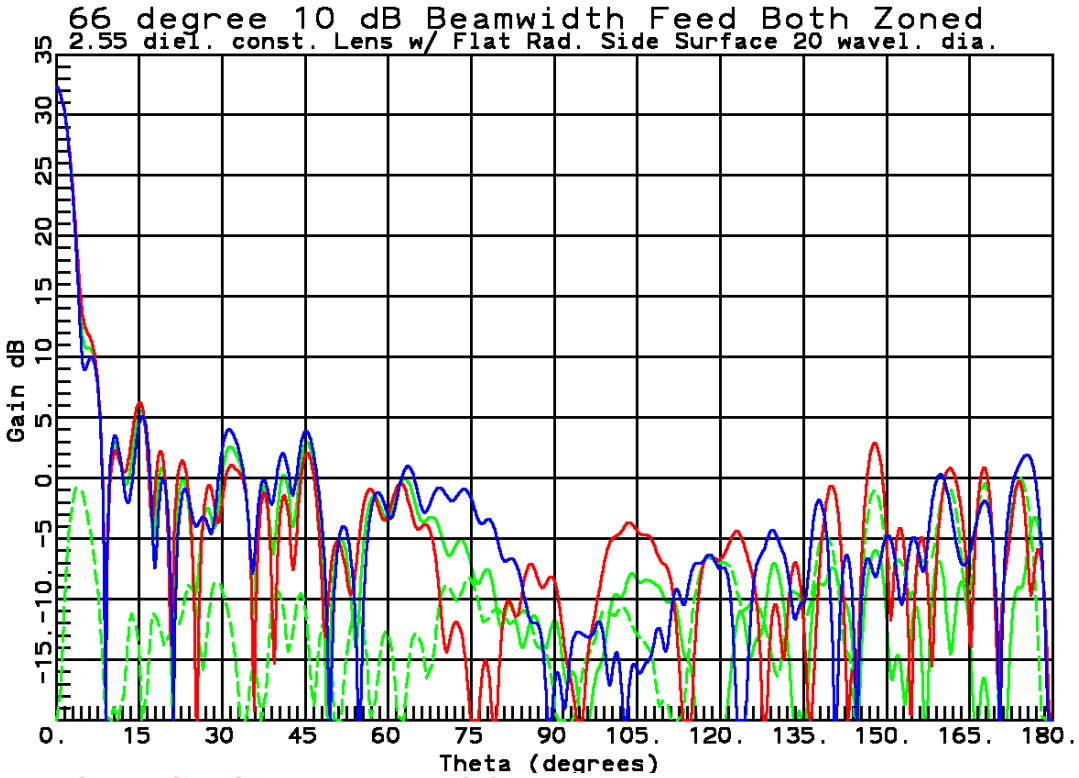
Blue: *E*-plane, Red: *H*-plane, Green: Diagonal plane



Blue: *E*-plane, Red: *H*-plane, Green: Diagonal plane

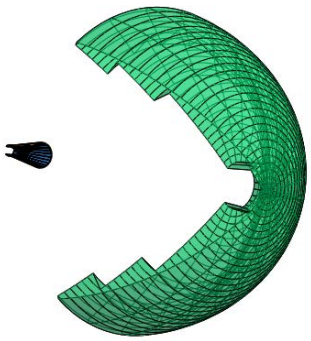
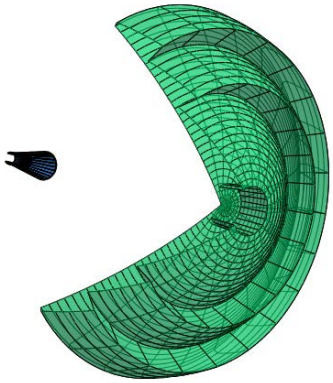
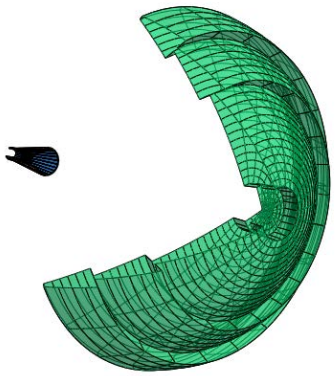


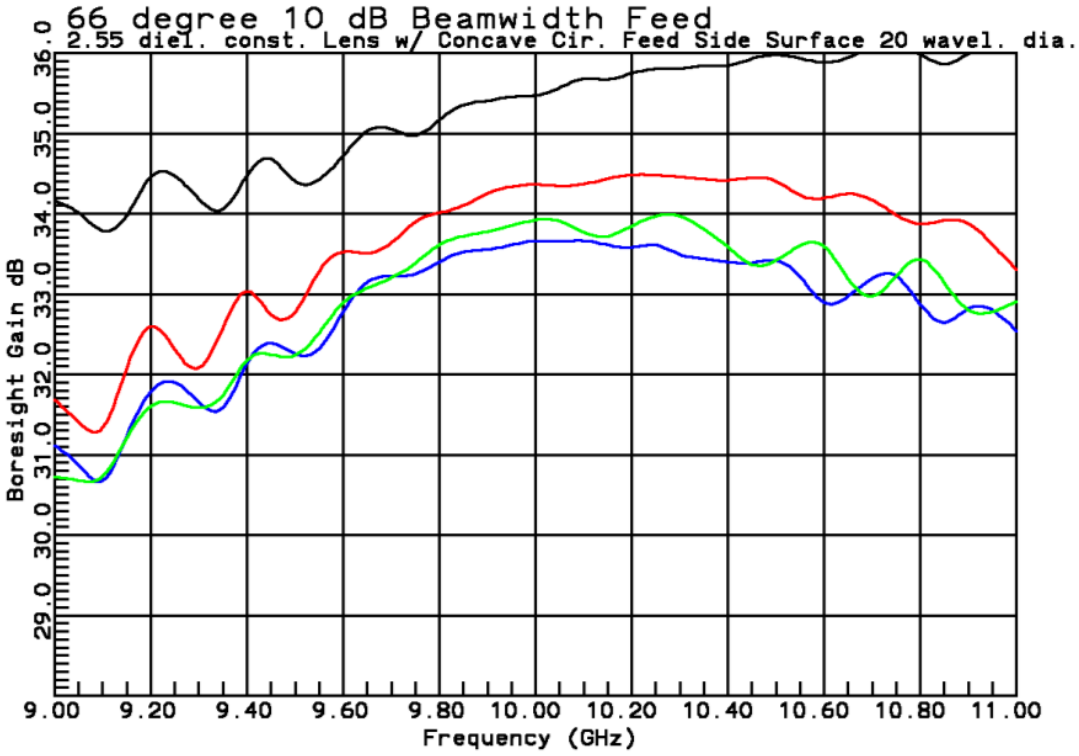
Blue: *E*-plane, Red: *H*-plane, Green: Diagonal plane



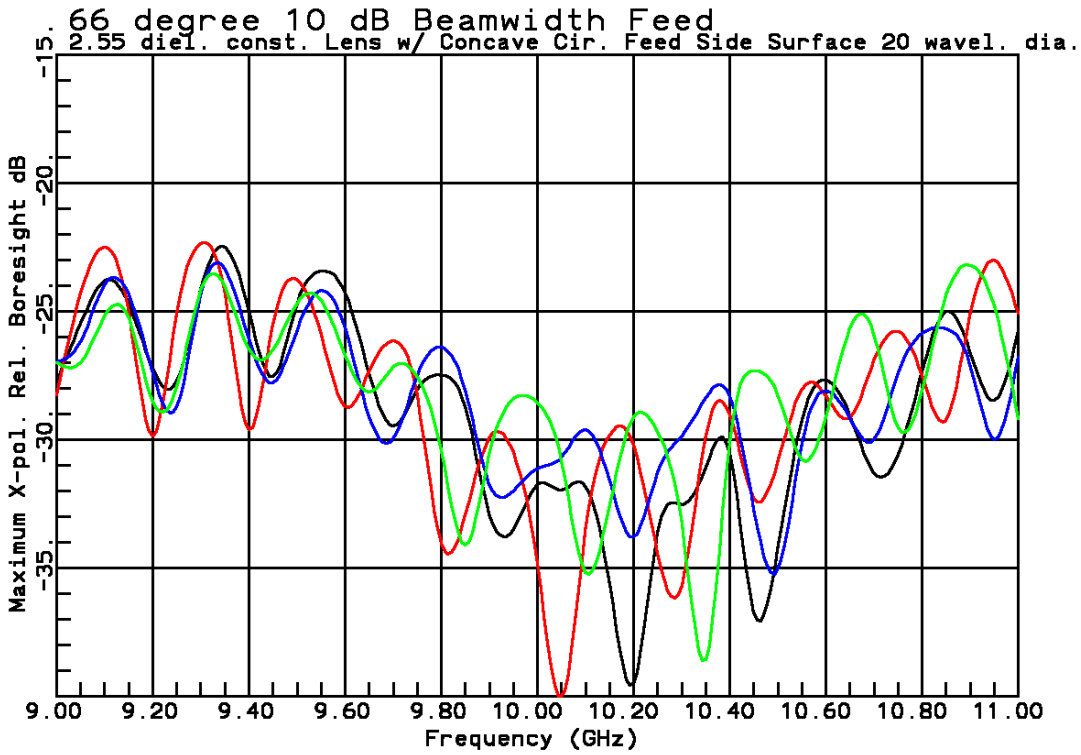
Blue: *E*-plane, Red: *H*-plane, Green: Diagonal plane

Concave Sphere Feed Side

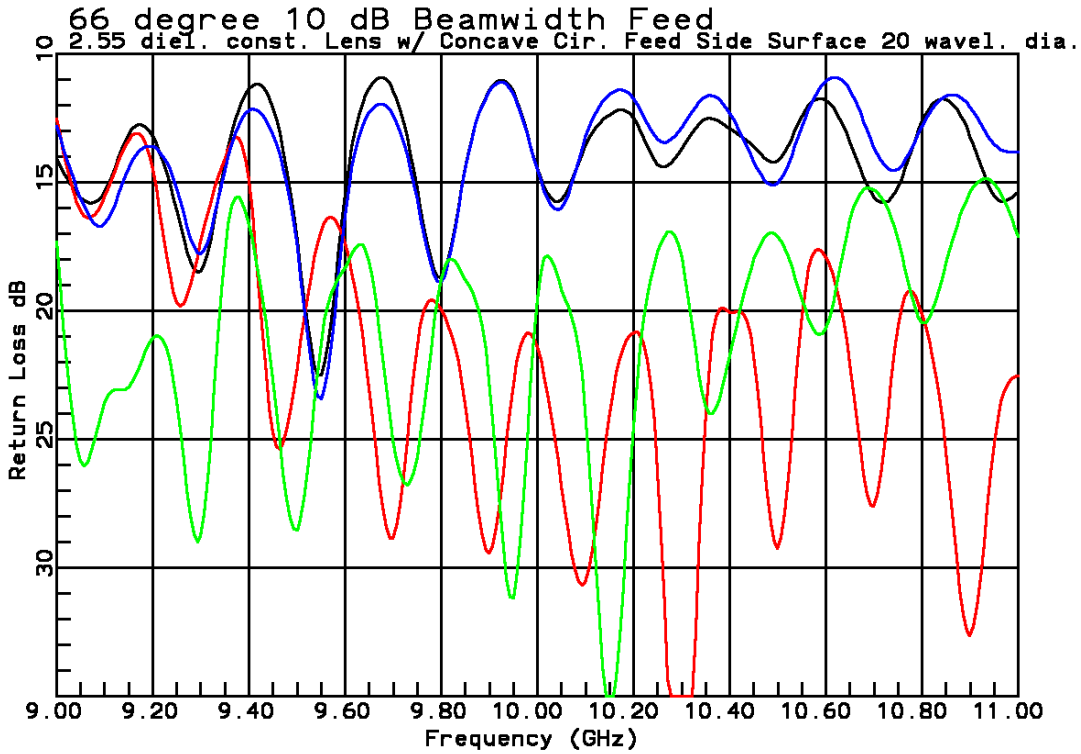
Feed Side Zoning	Radiation Side Zoning	Combined Zoning
		



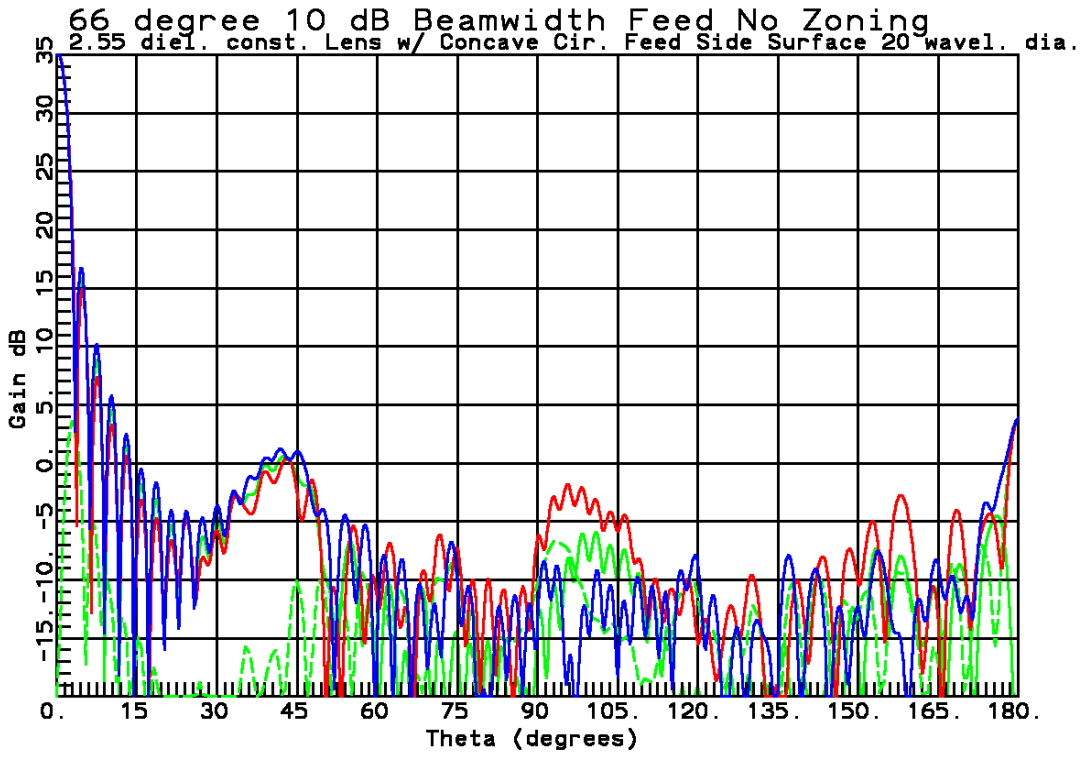
Black: no zoning, Red: Feed side zoning, Blue: Radiation side zoning, Green: Combined zoning



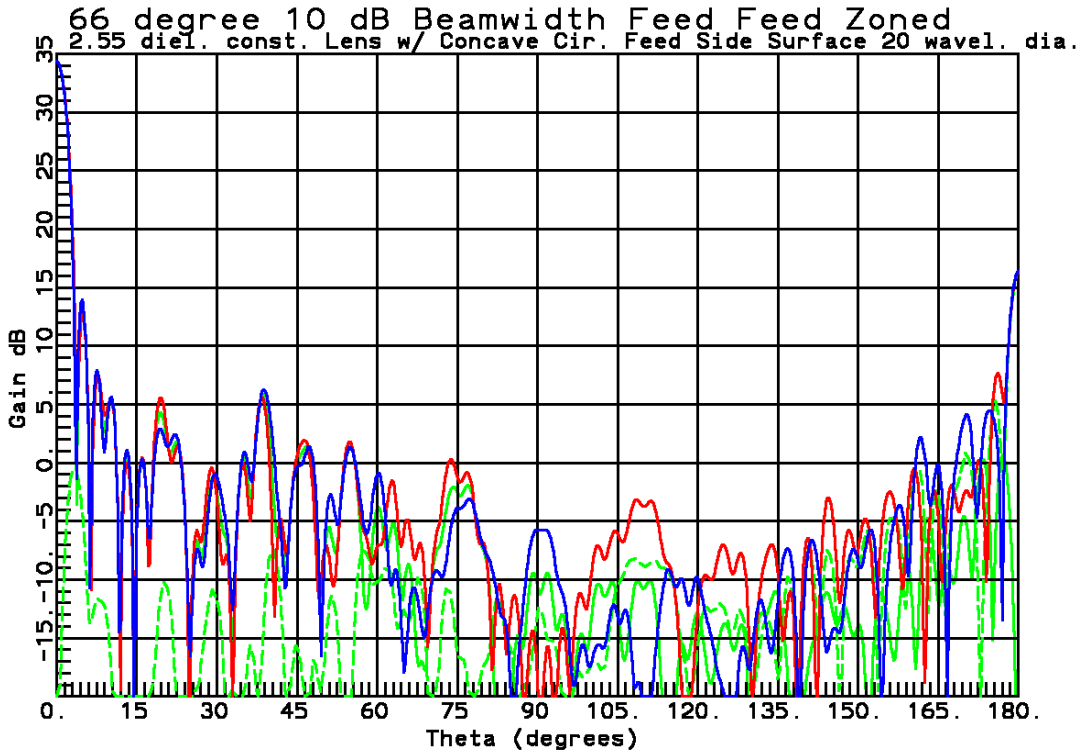
Black: no zoning, Red: Feed side zoning, Blue: Radiation side zoning, Green: Combined zoning



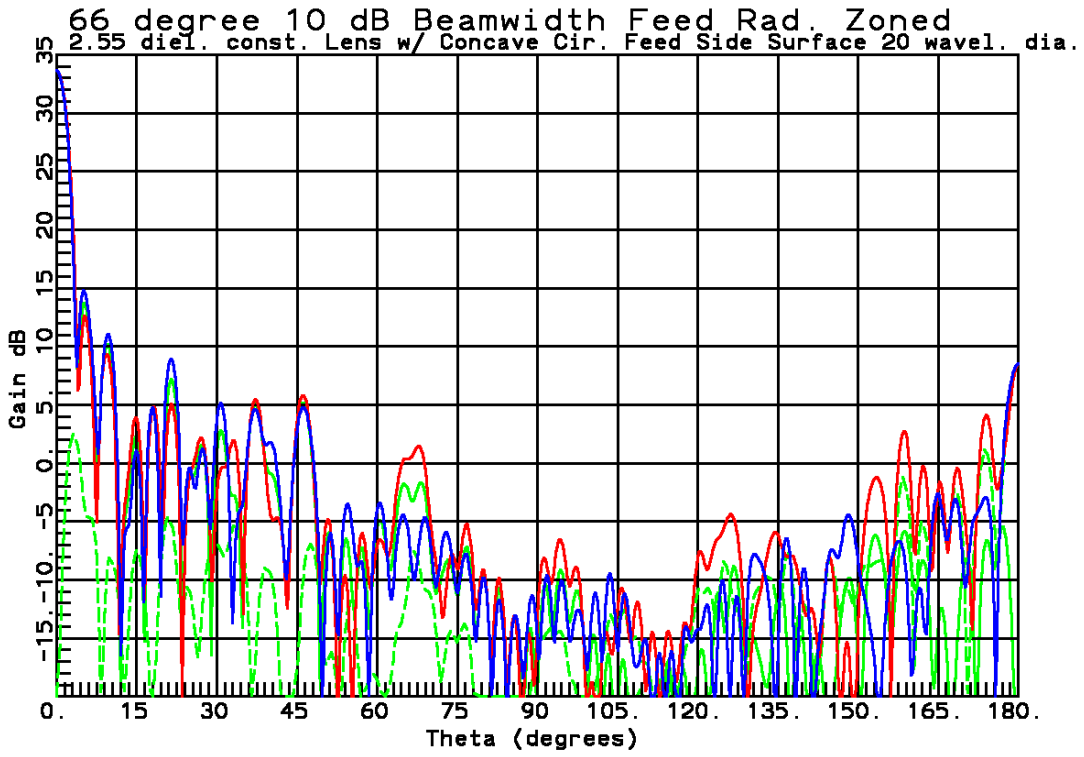
Black: no zoning, Red: Feed side zoning, Blue: Radiation side zoning, Green: Combined zoning



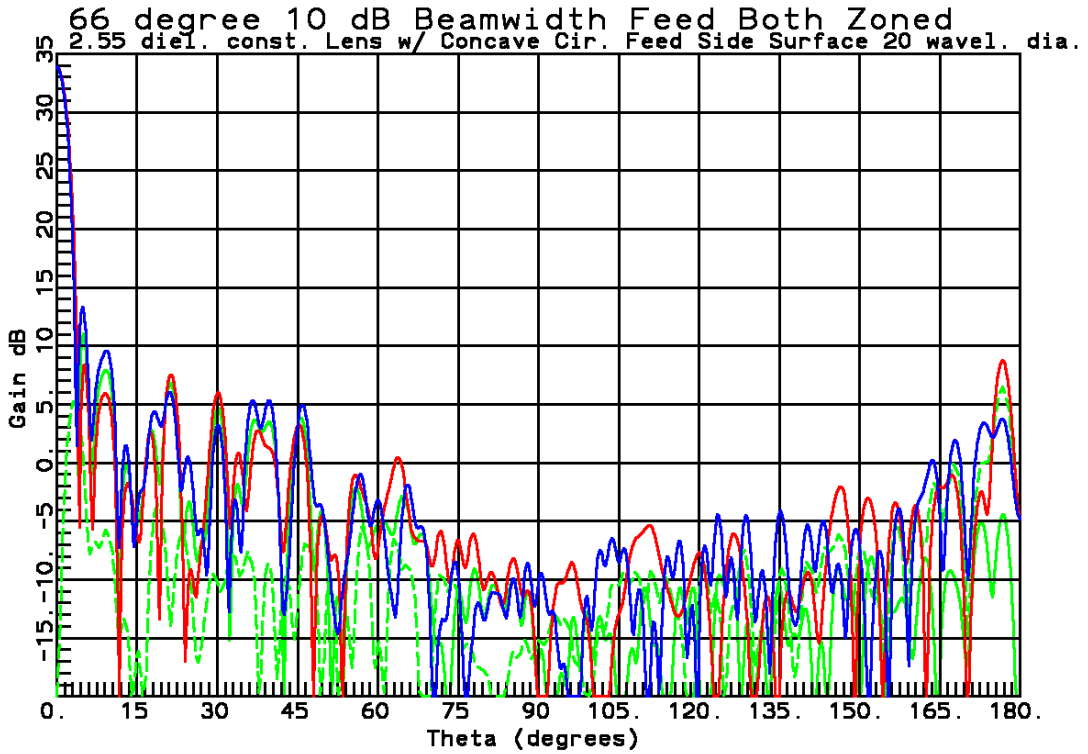
Blue: *E*-plane, Red: *H*-plane, Green: Diagonal plane



Blue: *E*-plane, Red: *H*-plane, Green: Diagonal plane

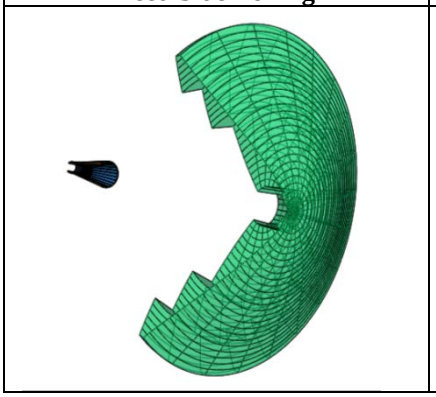
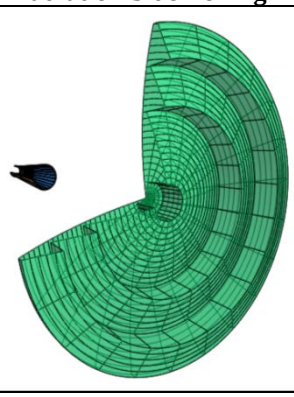
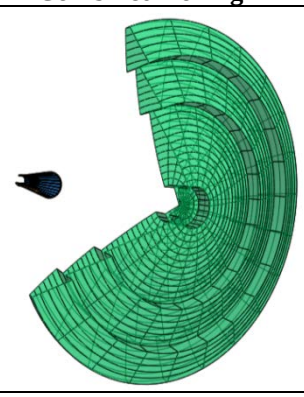


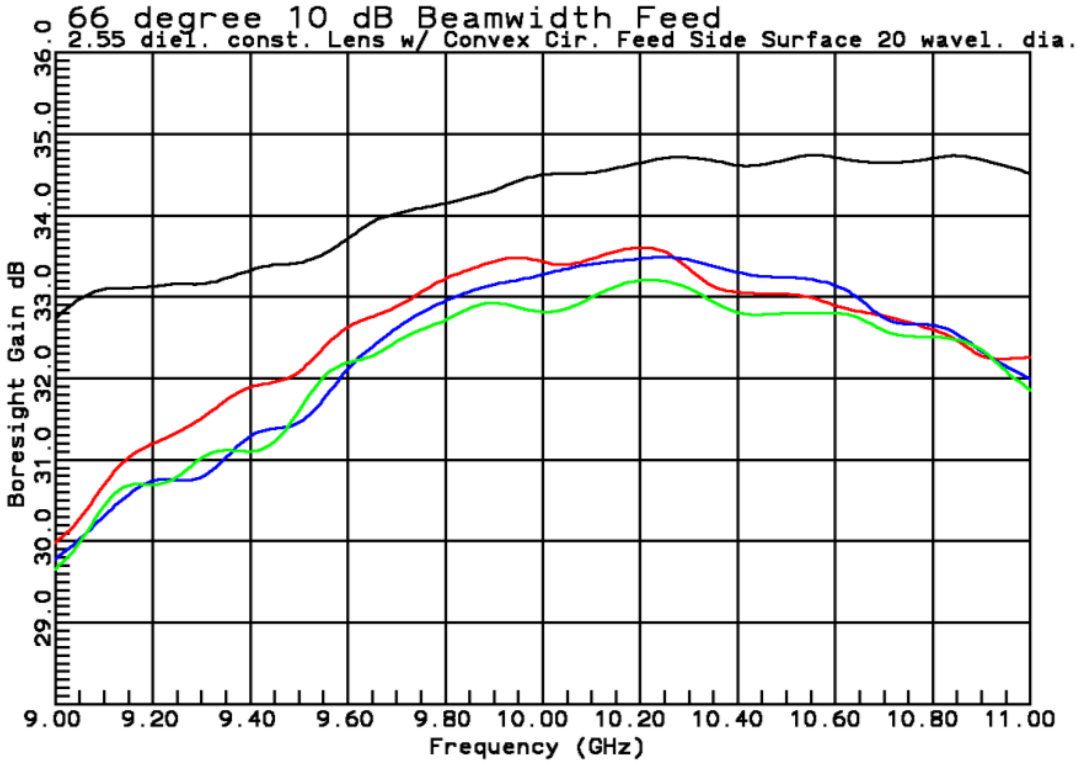
Blue: *E*-plane, Red: *H*-plane, Green: Diagonal plane



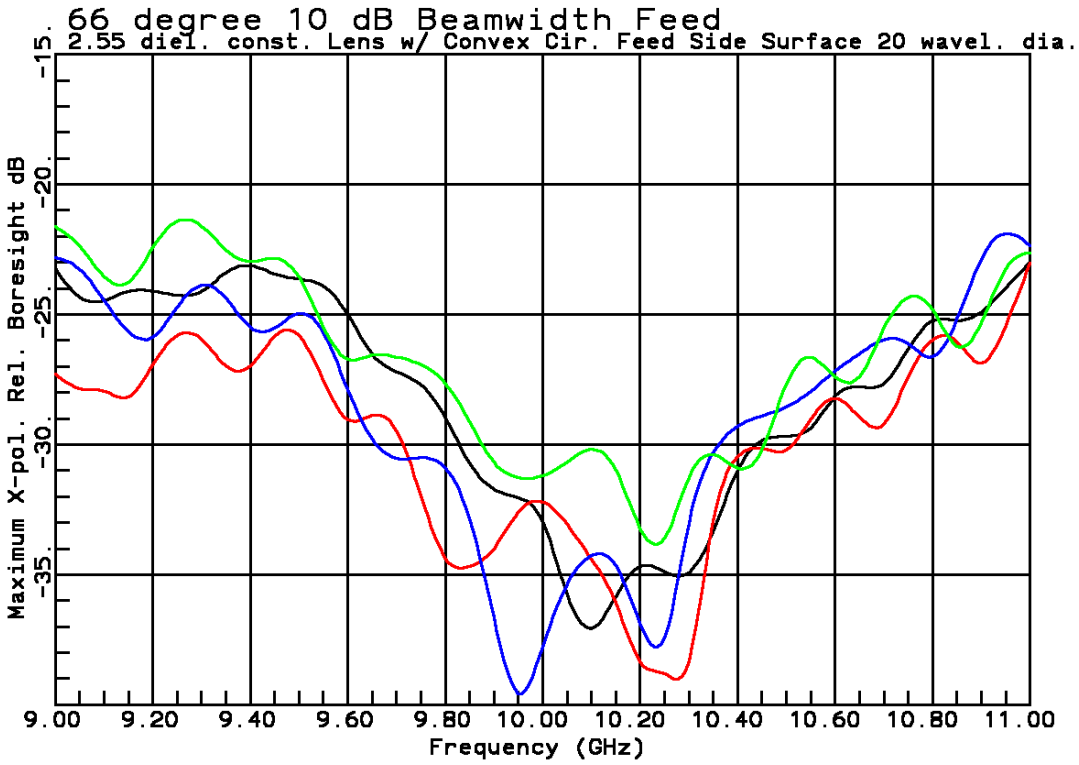
Blue: *E*-plane, Red: *H*-plane, Green: Diagonal plane

Convex Sphere Feed Side

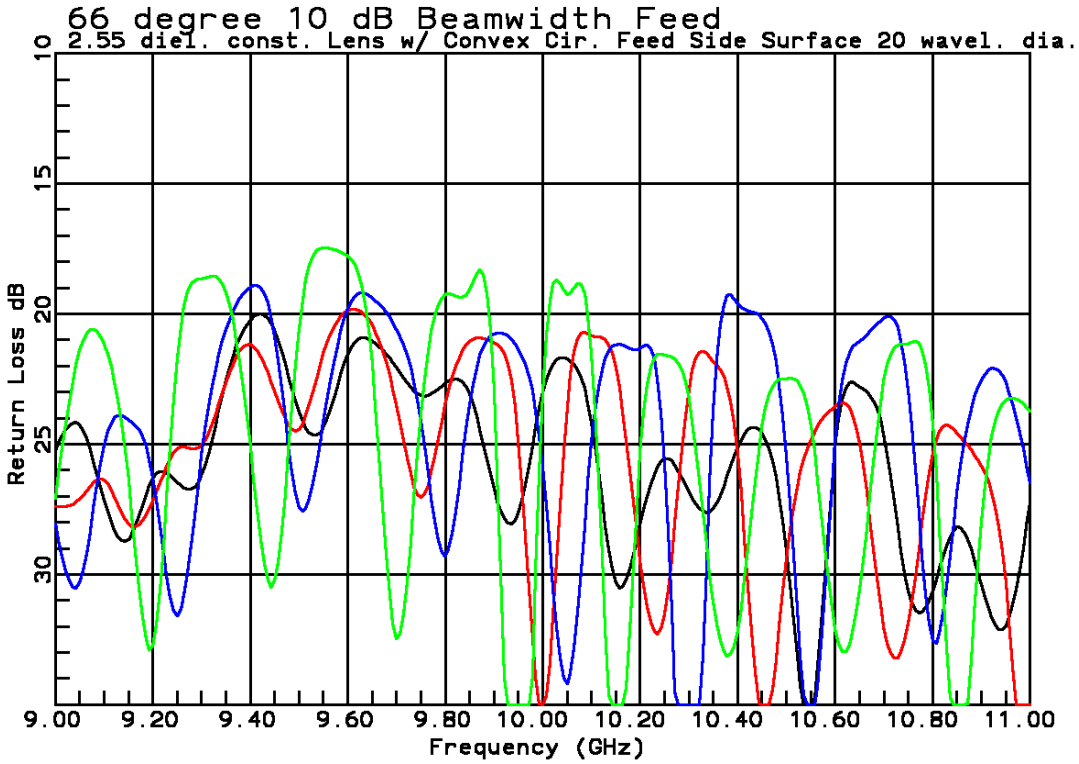
Feed Side Zoning	Radiation Side Zoning	Combined Zoning
		



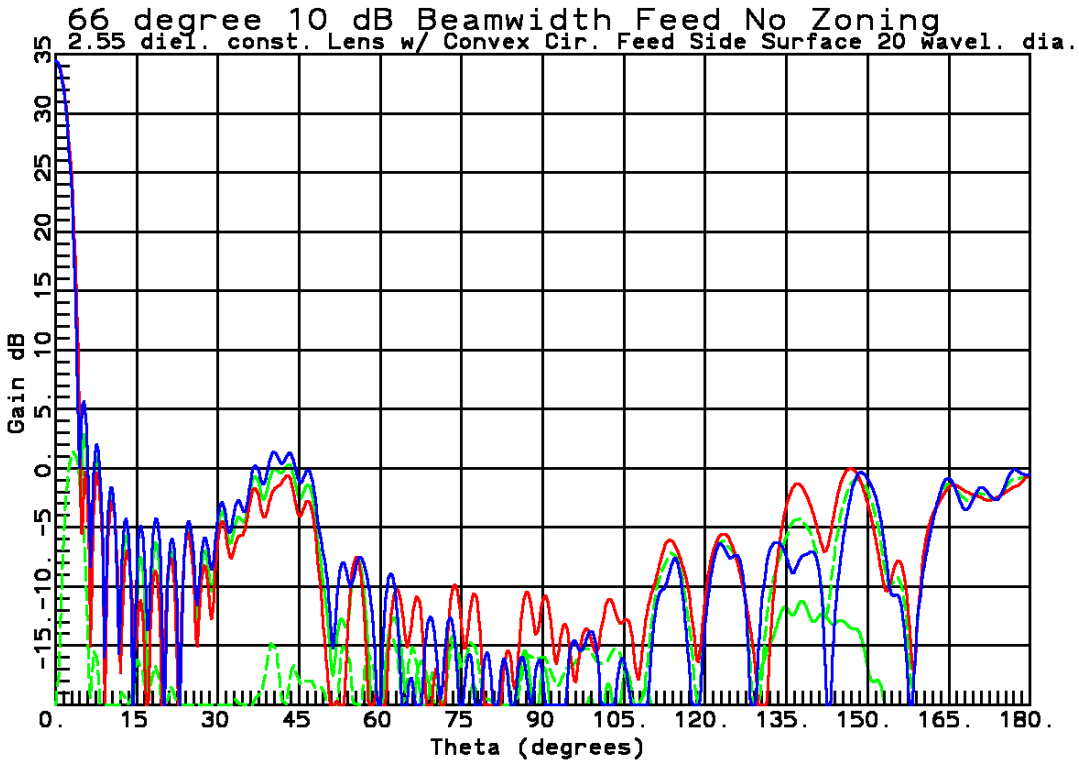
Black: no zoning, Red: Feed side zoning, Blue: Radiation side zoning, Green: Combined zoning



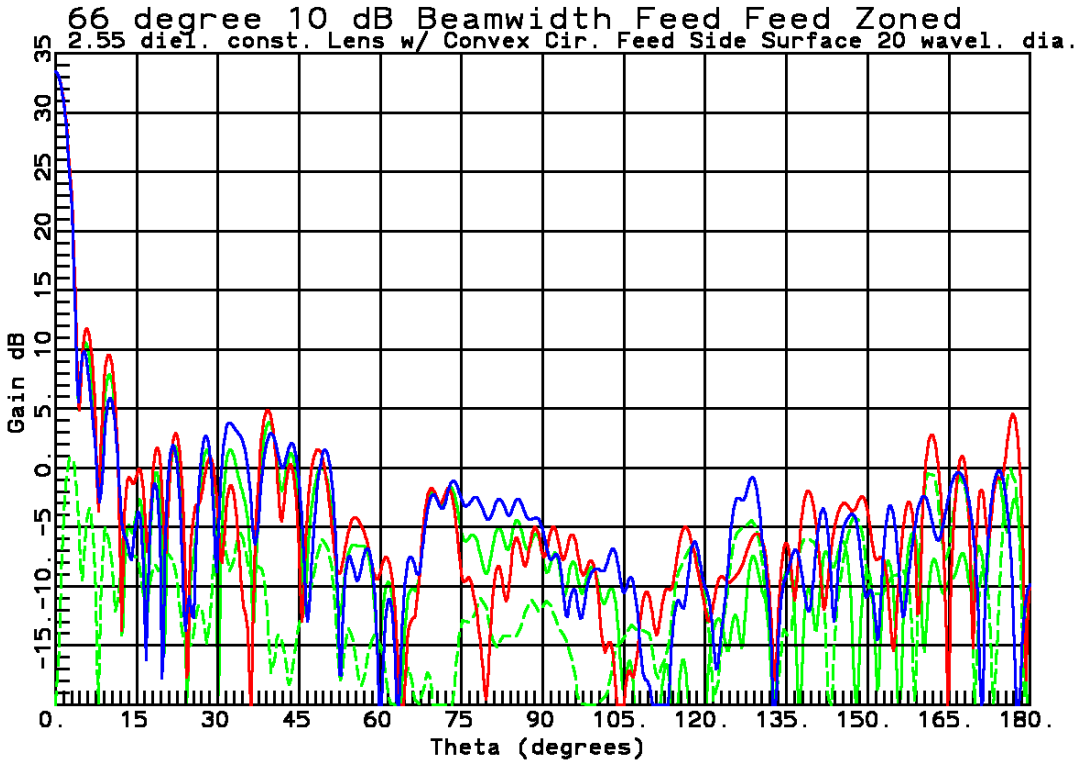
Black: no zoning, Red: Feed side zoning, Blue: Radiation side zoning, Green: Combined zoning



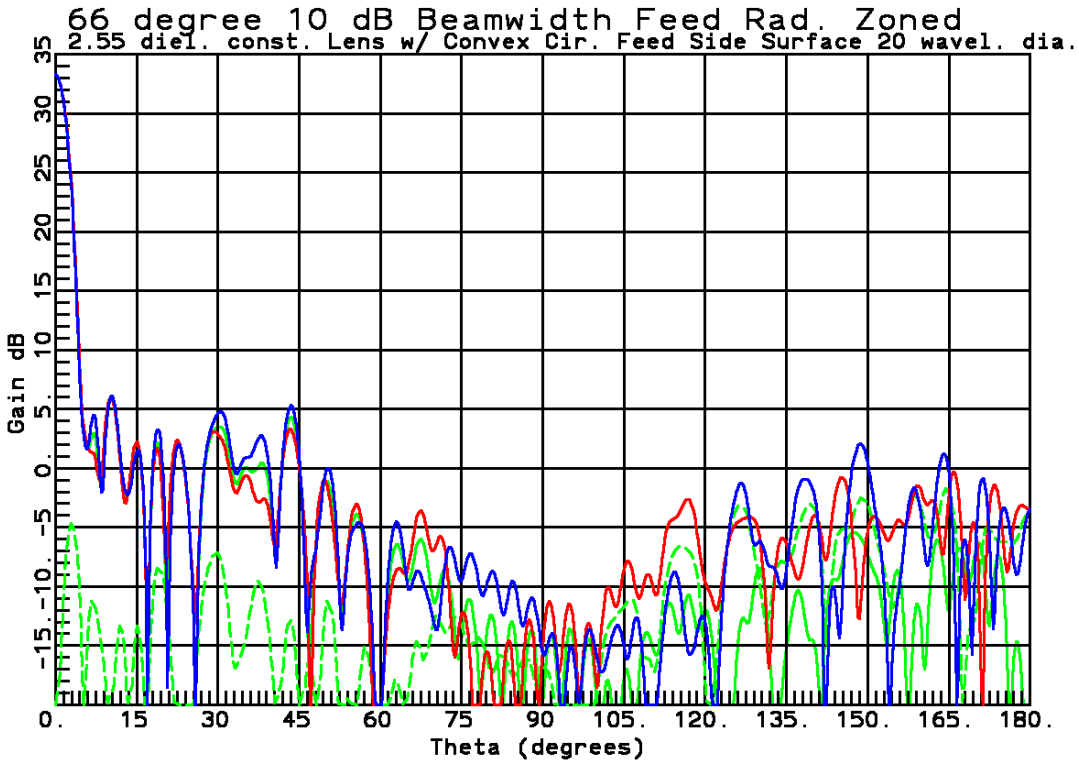
Black: no zoning, Red: Feed side zoning, Blue: Radiation side zoning, Green: Combined zoning



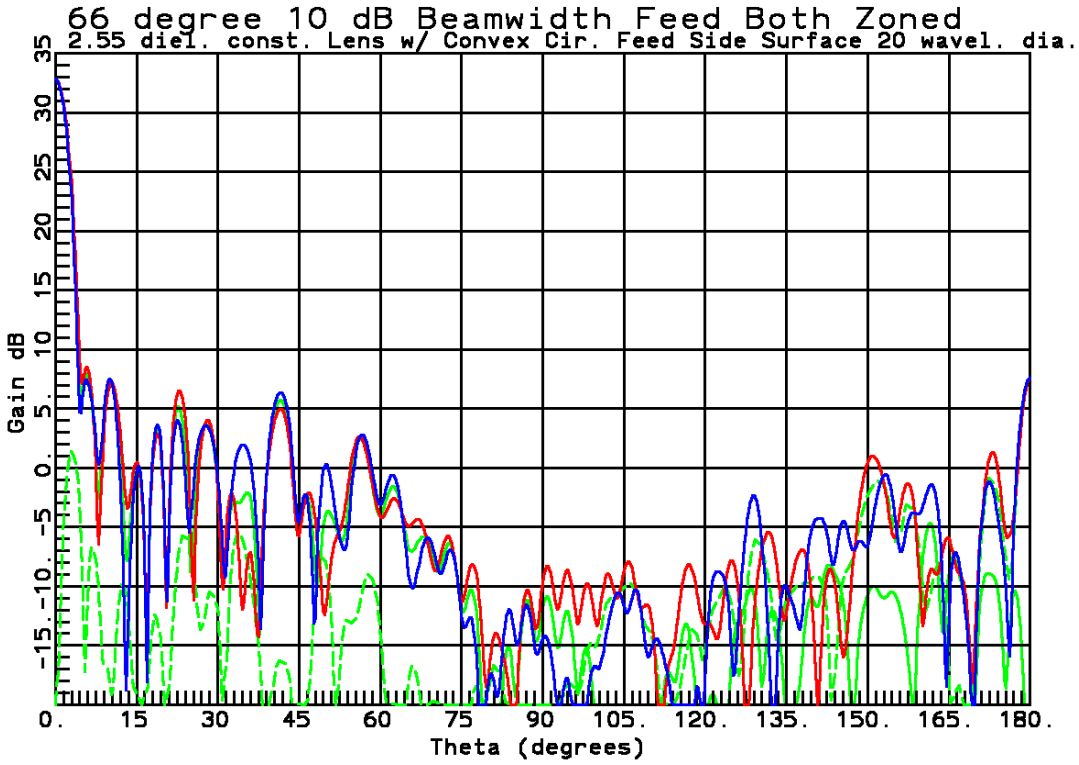
Blue: *E*-plane, Red: *H*-plane, Green: Diagonal plane



Blue: *E*-plane, Red: *H*-plane, Green: Diagonal plane

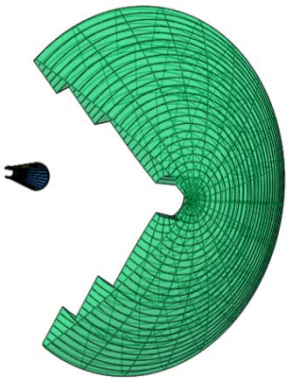
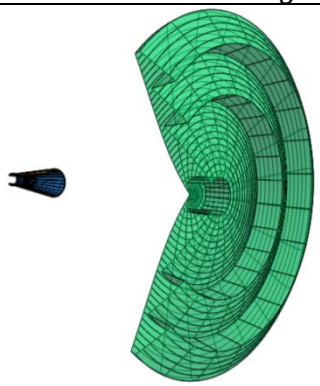
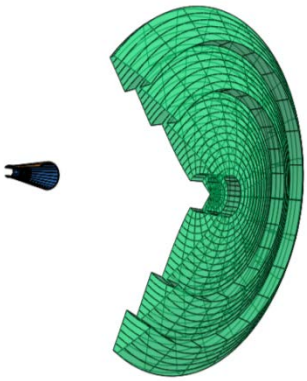


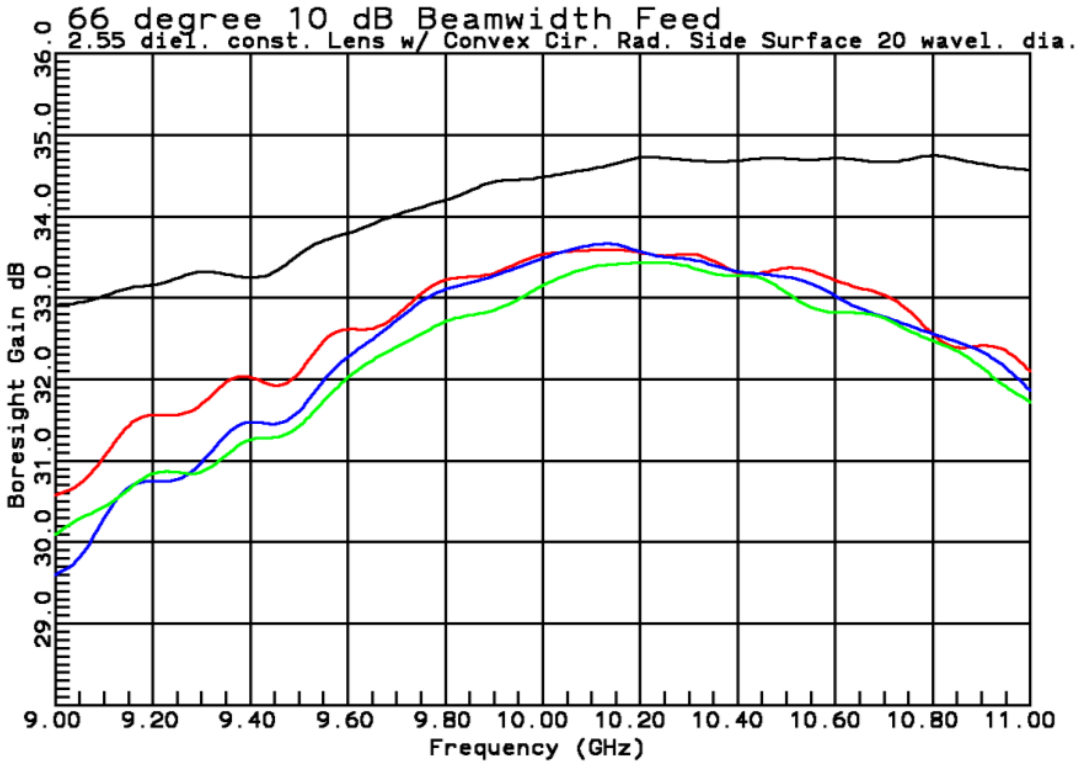
Blue: *E*-plane, Red: *H*-plane, Green: Diagonal plane



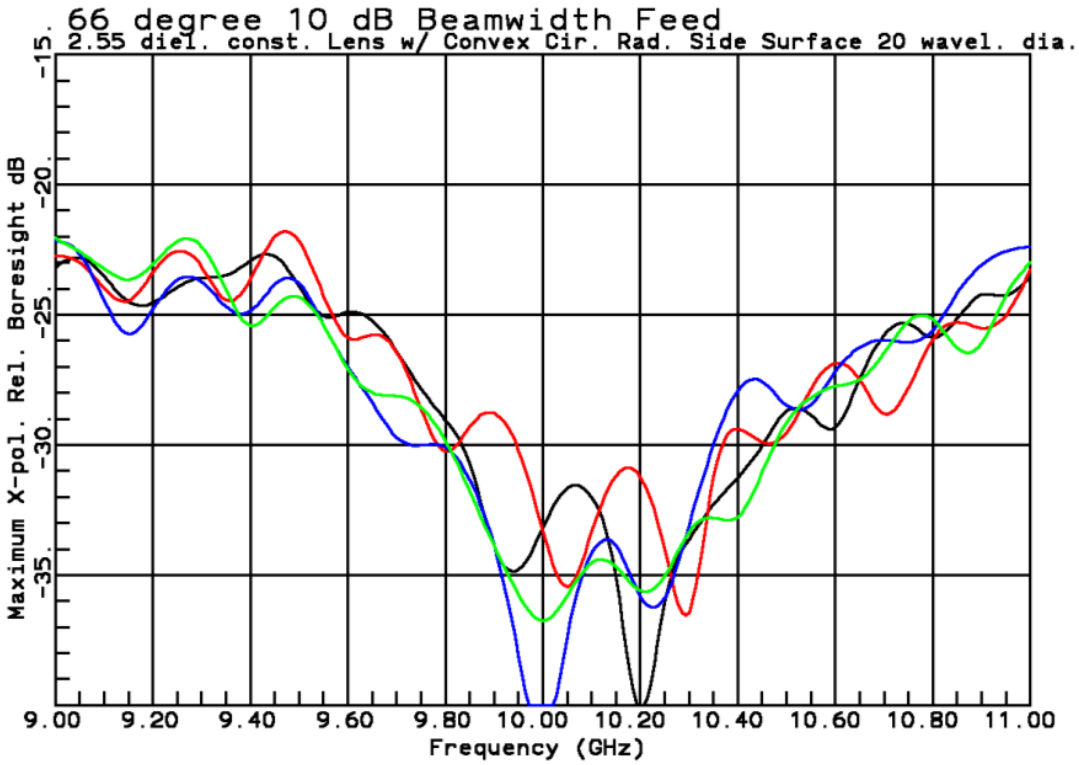
Blue: *E*-plane, Red: *H*-plane, Green: Diagonal plane

Convex Sphere Radiation Side

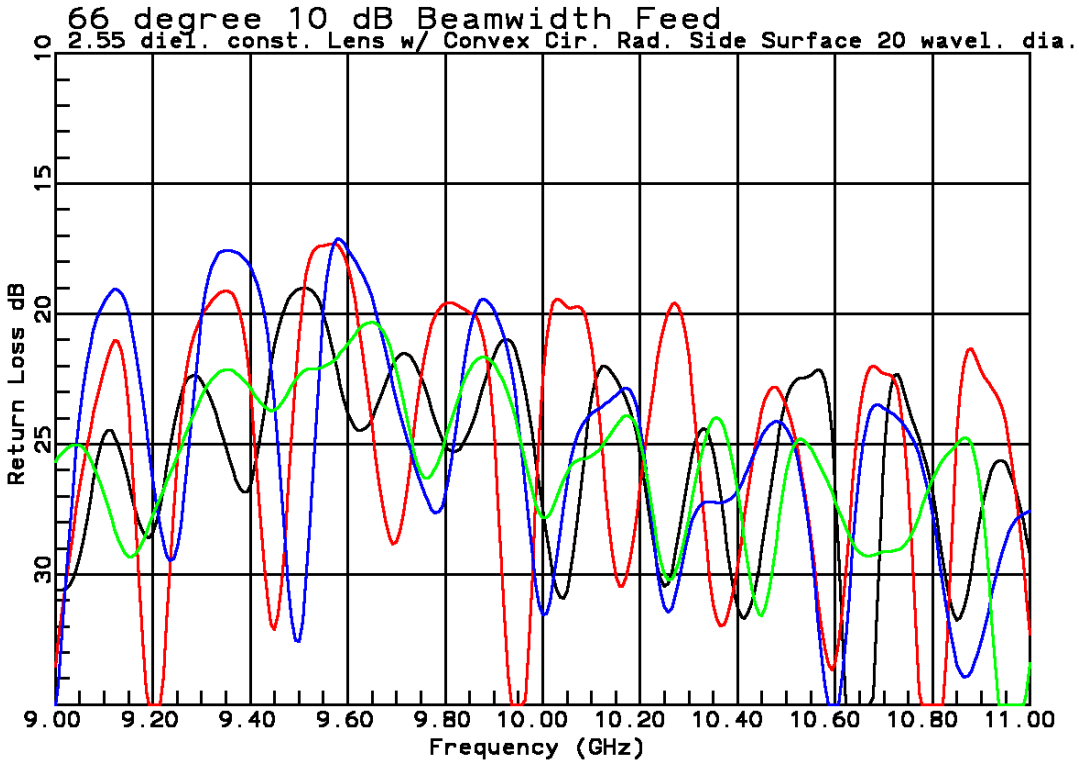
Feed Side Zoning	Radiation Side Zoning	Combined Zoning
		



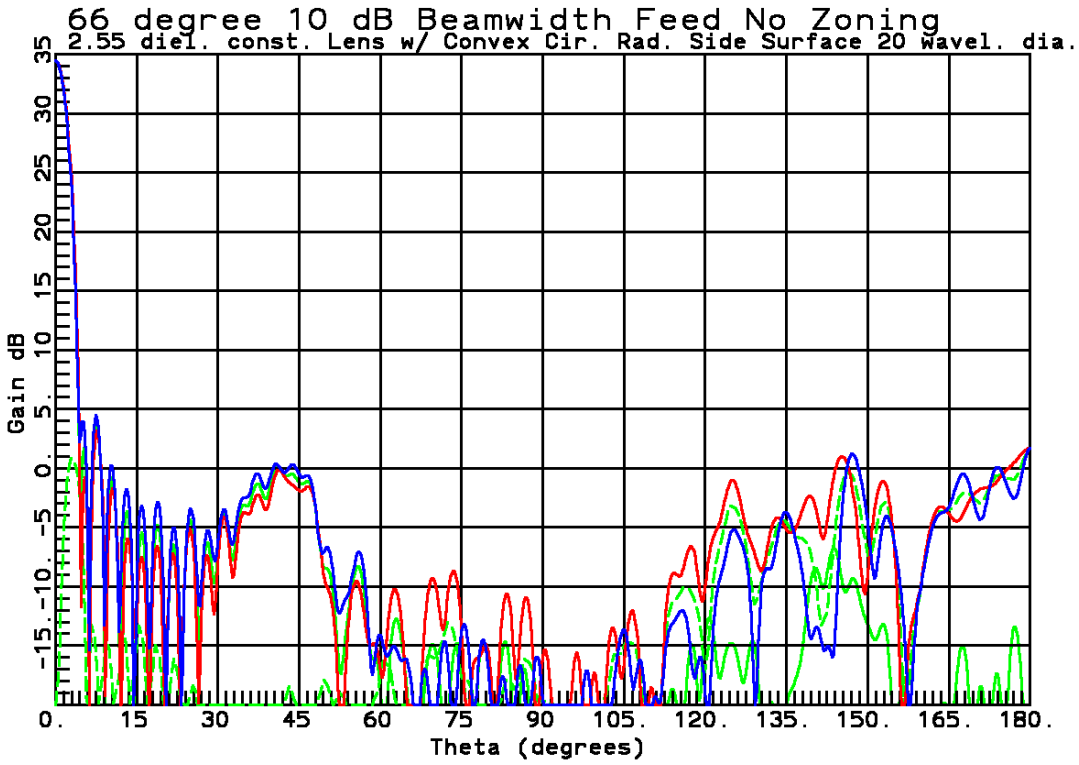
Black: no zoning, Red: Feed side zoning, Blue: Radiation side zoning, Green: Combined zoning



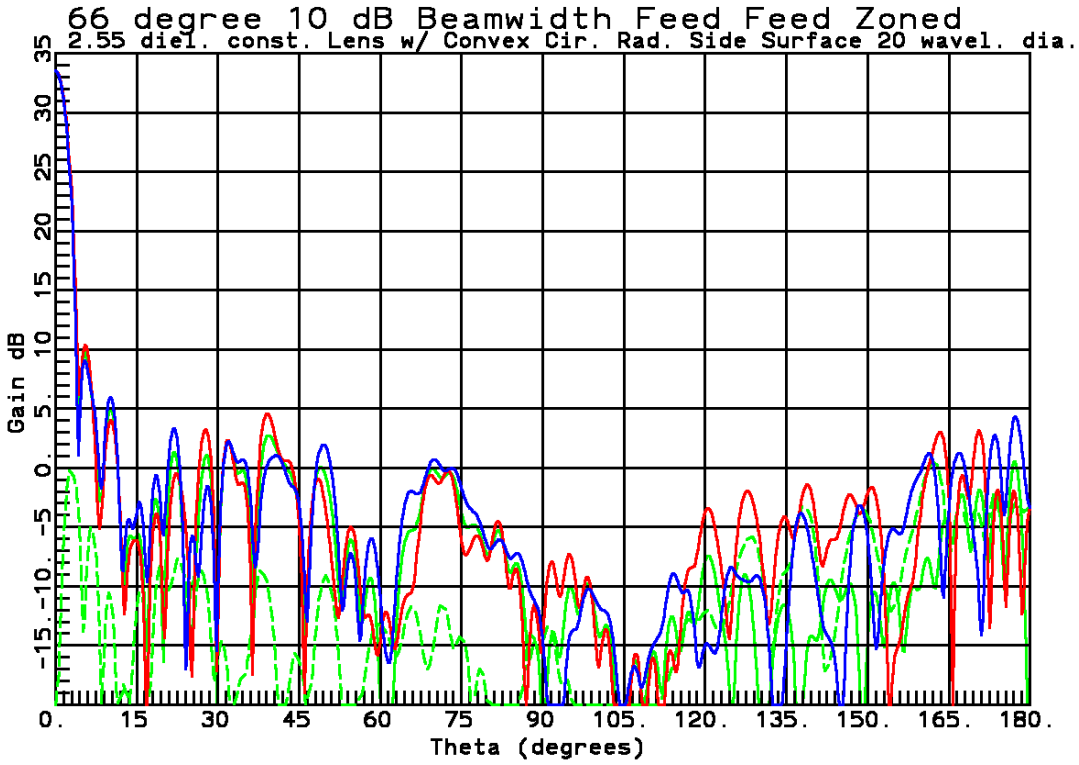
Black: no zoning, Red: Feed side zoning, Blue: Radiation side zoning, Green: Combined zoning



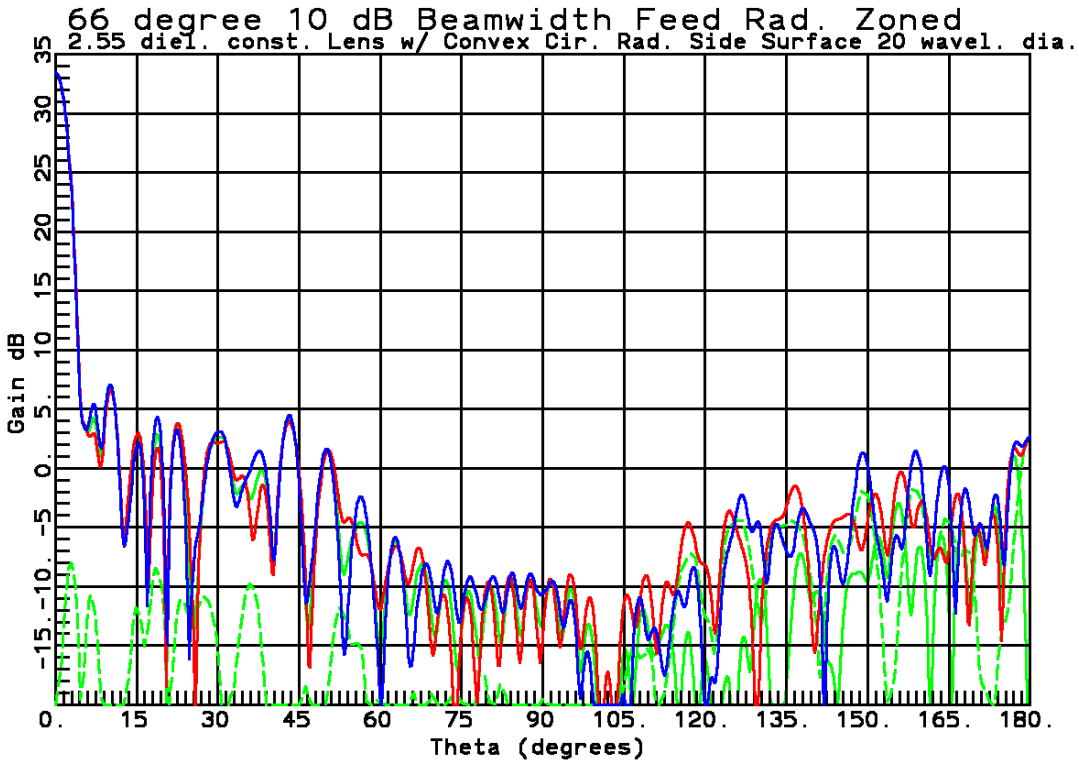
Black: no zoning, Red: Feed side zoning, Blue: Radiation side zoning, Green: Combined zoning



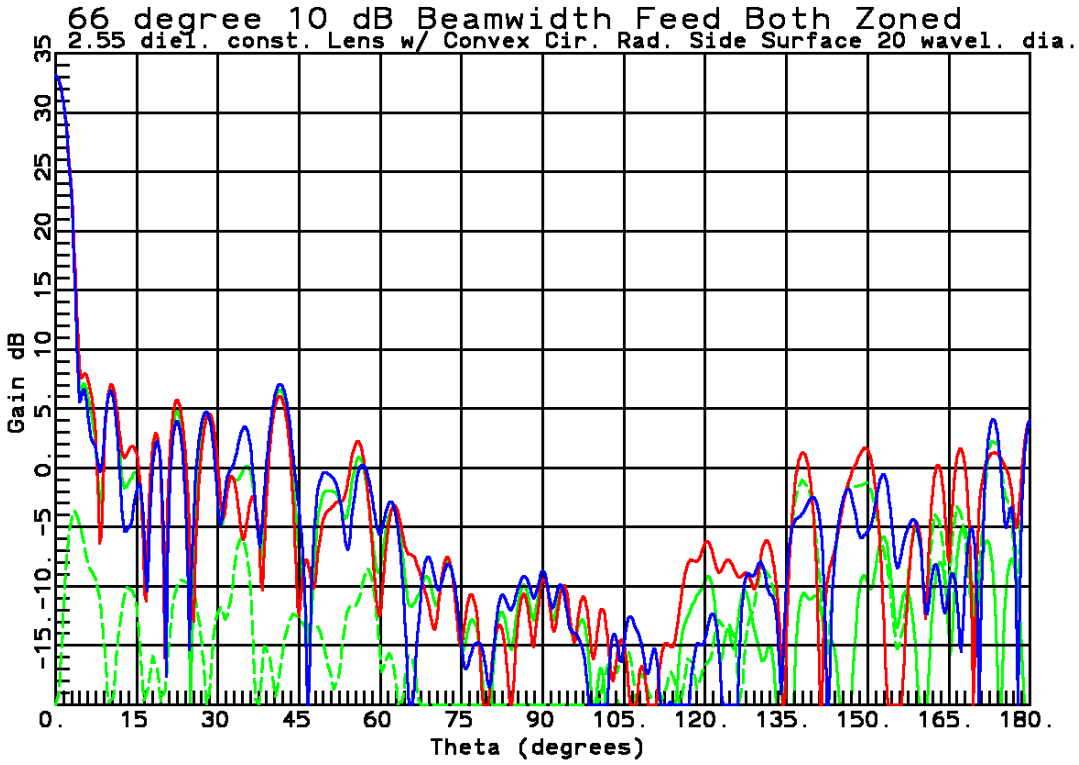
Blue: *E*-plane, Red: *H*-plane, Green: Diagonal plane



Blue: *E*-plane, Red: *H*-plane, Green: Diagonal plane

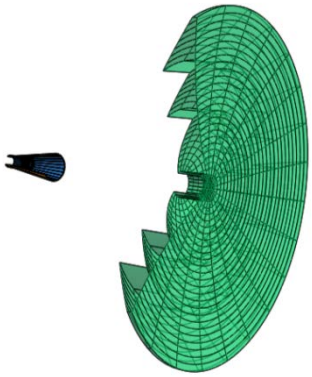
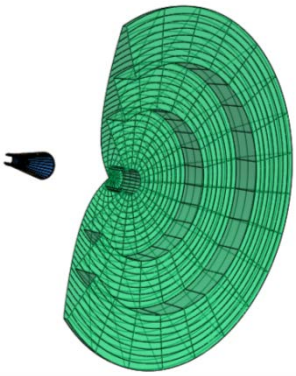
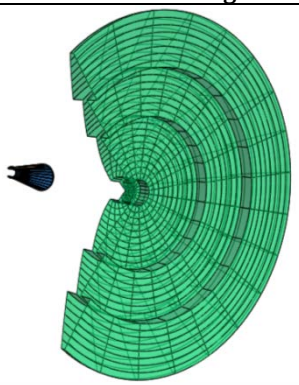


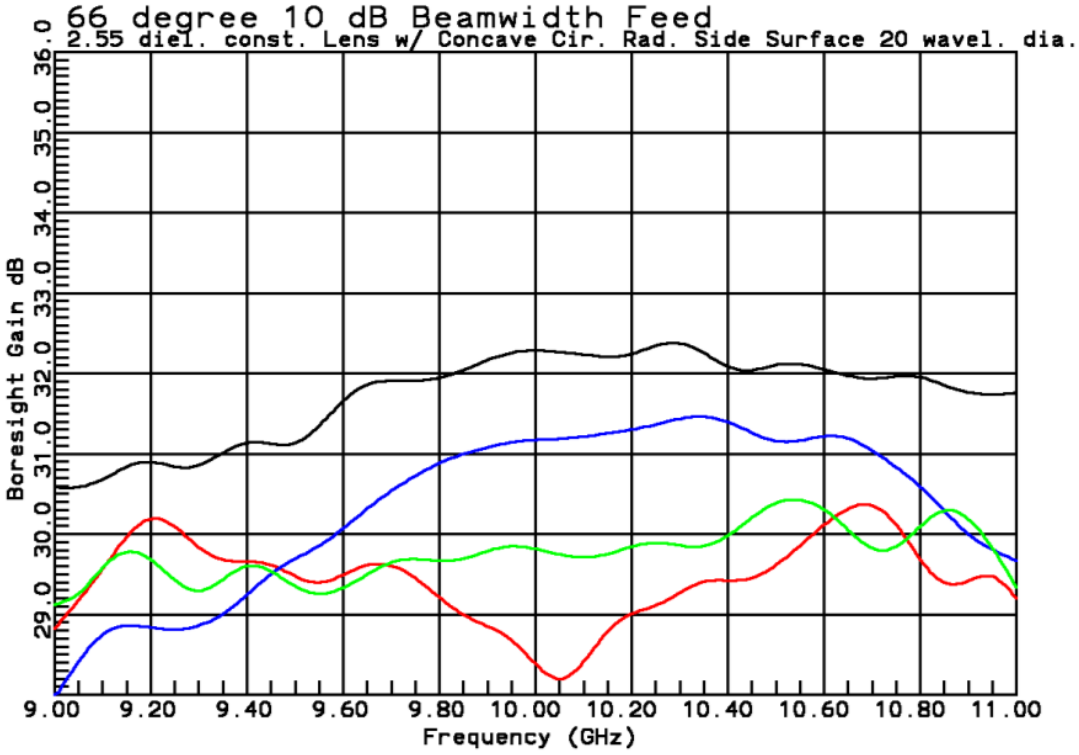
Blue: *E*-plane, Red: *H*-plane, Green: Diagonal plane



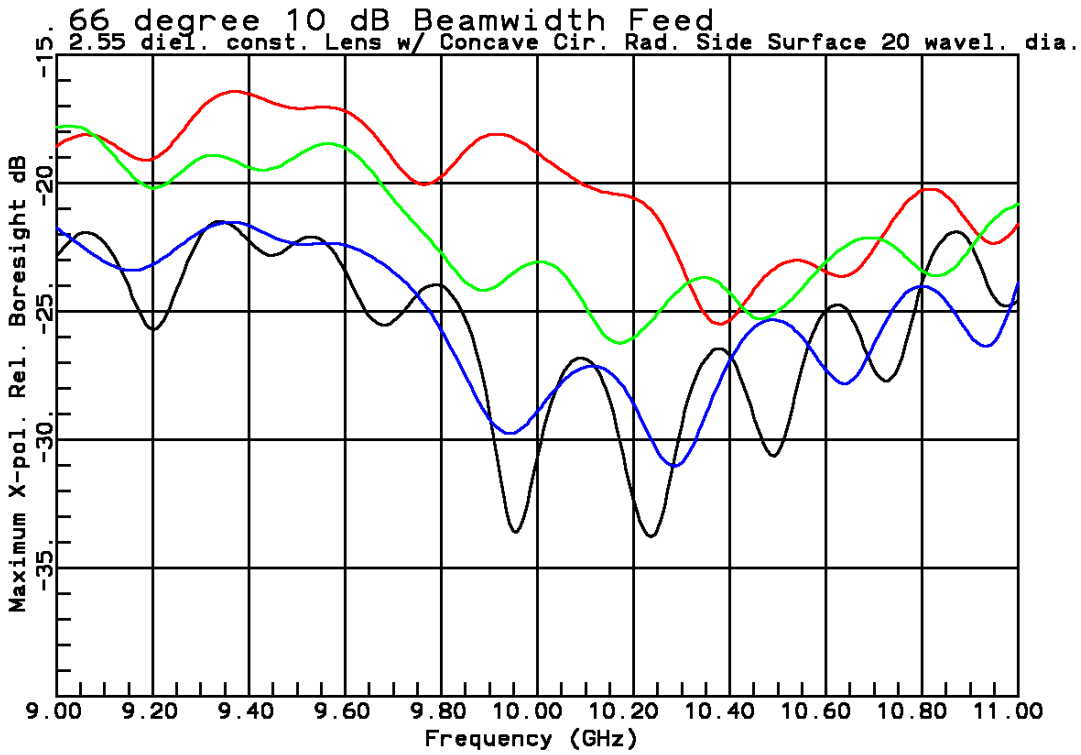
Blue: *E*-plane, Red: *H*-plane, Green: Diagonal plane

Concave Sphere Radiation Side

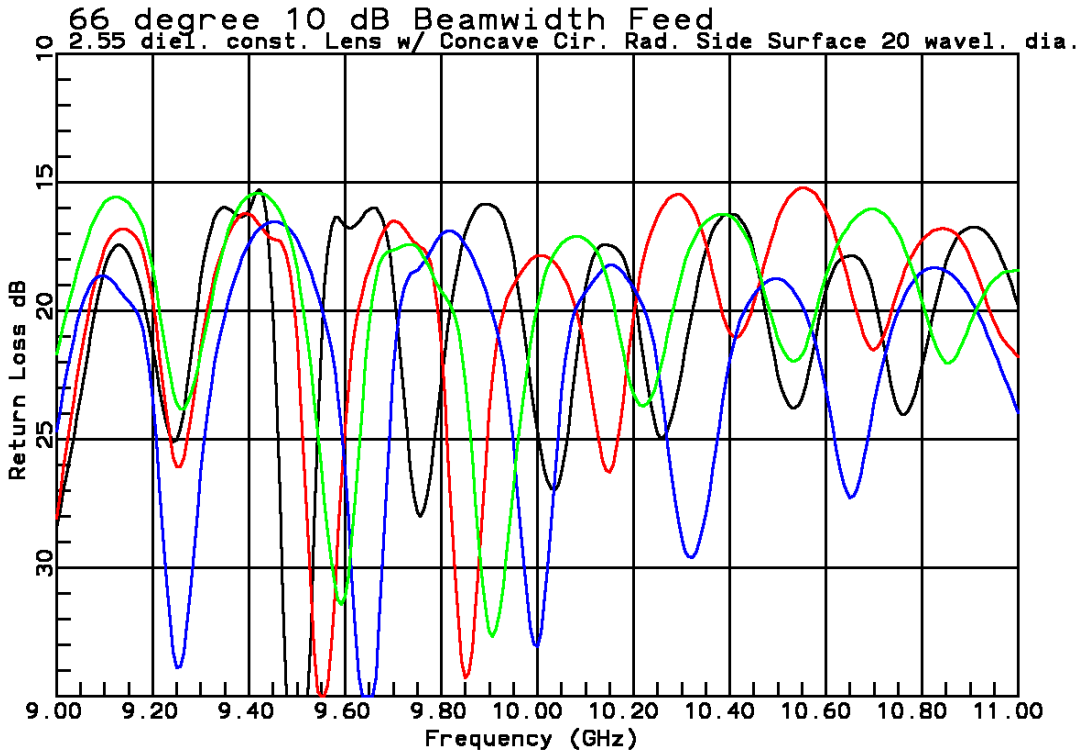
Feed Side Zoning	Radiation Side Zoning	Combined Zoning
		



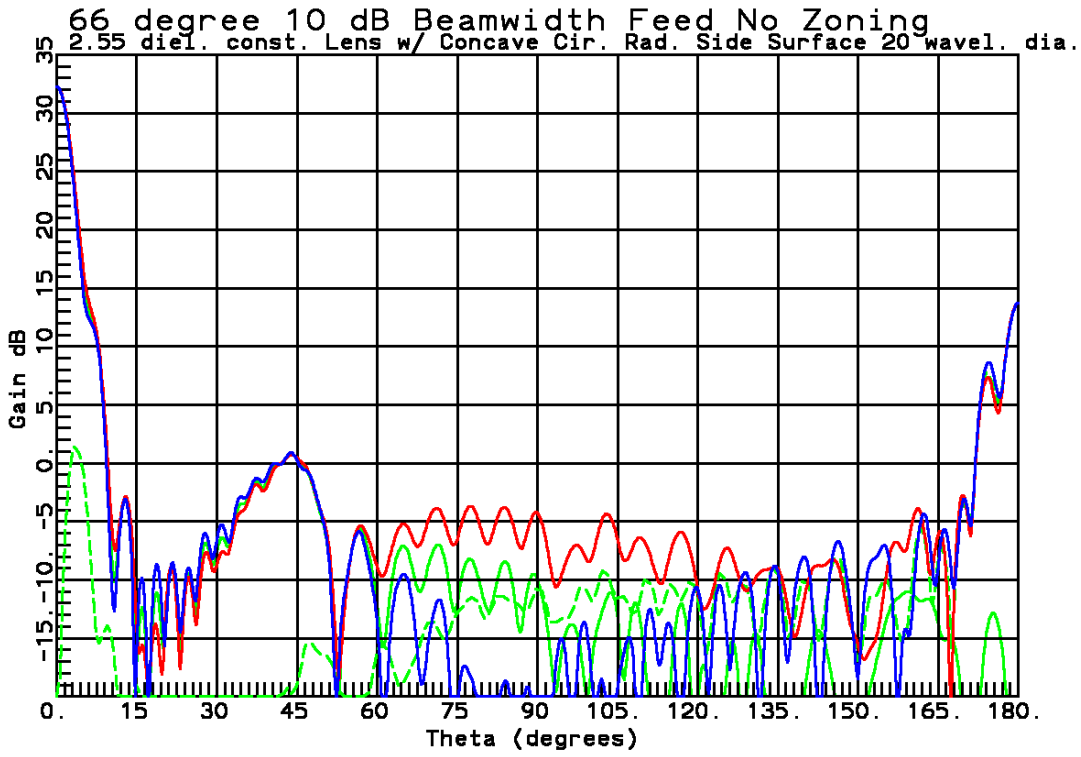
Black: no zoning, Red: Feed side zoning, Blue: Radiation side zoning, Green: Combined zoning



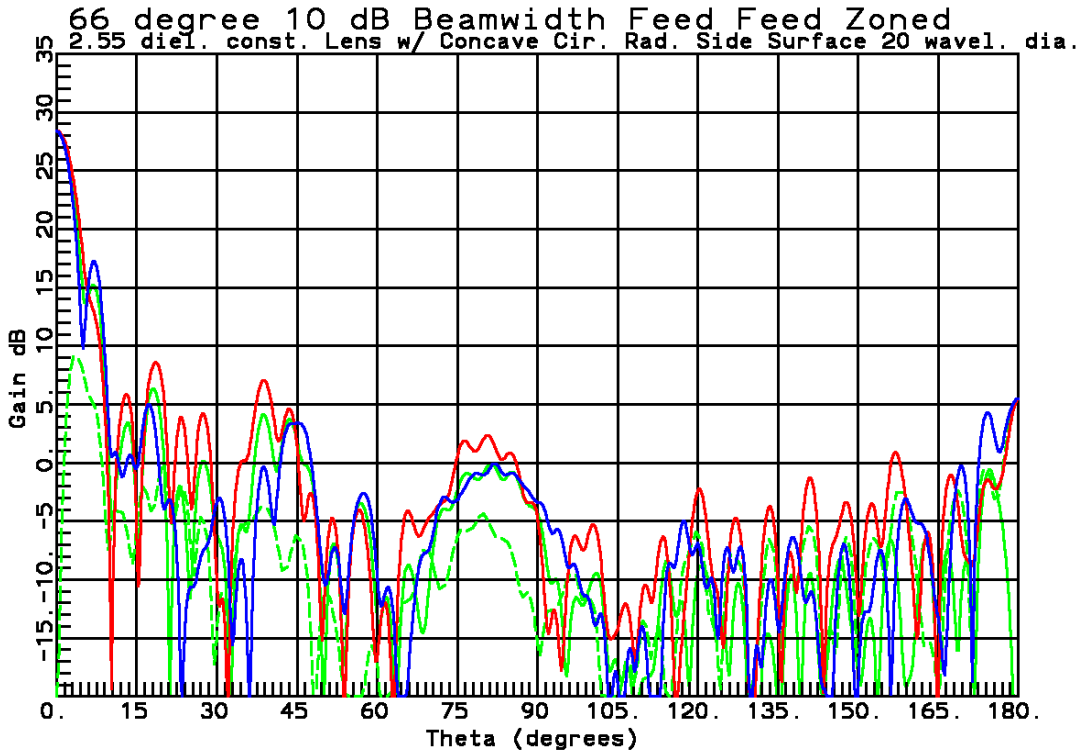
Black: no zoning, Red: Feed side zoning, Blue: Radiation side zoning, Green: Combined zoning



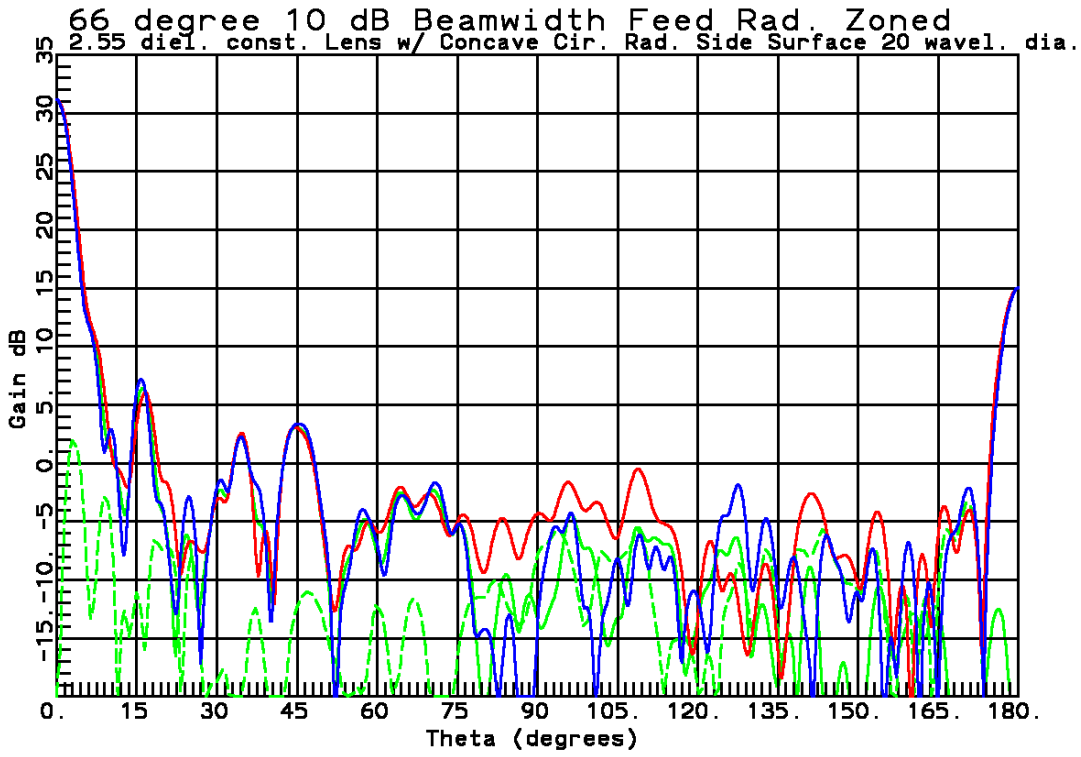
Black: no zoning, Red: Feed side zoning, Blue: Radiation side zoning, Green: Combined zoning



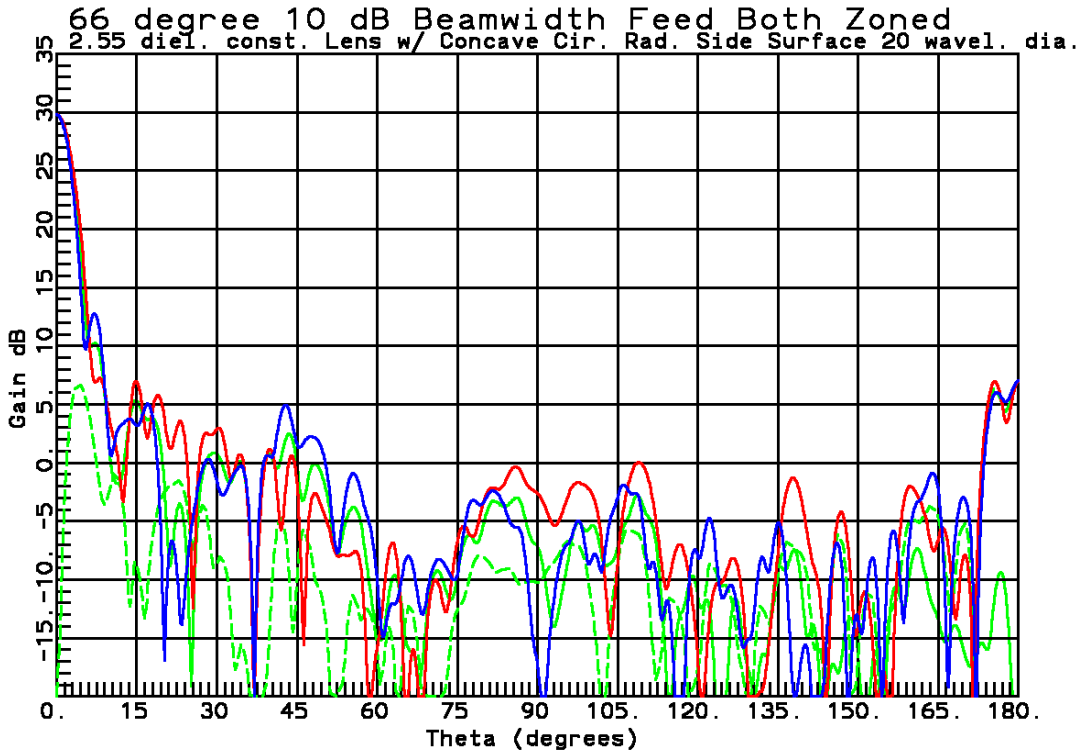
Blue: *E*-plane, Red: *H*-plane, Green: Diagonal plane



Blue: *E*-plane, Red: *H*-plane, Green: Diagonal plane



Blue: *E*-plane, Red: *H*-plane, Green: Diagonal plane



Blue: *E*-plane, Red: *H*-plane, Green: Diagonal plane

Adding SPZLENS output to geometry.tor file of CHAMP feed horn

The program SPZLENS was written to compute zoned versions of the two lens surfaces with one specified as either a flat or sphere. The program also generates the additions to the geometry.tor CHAMP file to add the lens to the analysis of the feed-lens combination. The file includes a ZLOFF parameter to allow arbitrary positioning of the lens. Cases below have the lens focus moved inside the horn aperture to its phase center. Since the lens could be in the near-field of the feed horn, this parameter could be used as an optimization variable to maximize gain.
After the feed horn is designed, the project files can be copied into another project before altering the geometry.tor file located in the top directory of feed subdirectory. Below is a listing of the 14.5 dB gain Pickett-Potter horn geometry.tor file with the lens added using a text editor. The additions are printed in blue with some of the repetitive lines removed.

```
horn  combined_horn_section
(
  horn_sections    : sequence(ref(circular_waveguide_section),ref(smooth_horn_section),
ref(smooth_horn_section_0001),ref(smooth_horn_section_0002)),
  scatterers       : sequence(ref(horn_bor_mesh),ref(horn_bor_mesh_lens)) Added scatterer
)
wavel  real_variable
(
  value          : 29.97925
)
length  real_variable
(
  value          : 92.86019175
)
rout  real_variable
(
  value          : 29.61470627
)
WR  real_variable
(
  value          : 13.0
)
rstep  real_variable
(
  value          : "0.65*ref(wavel)"
)
istep  real_variable
(
  value          : "0.51*ref(wavel)"
)
WL  real_variable
(
  value          : "ref(wavel)"
)
lenc  real_variable
(
  value          : "ref(length)*(ref(rstep)-ref(istep))/(ref(rout)-ref(rstep))"
)
leno  real_variable
(
  value          : "ref(length)*(ref(rout)-ref(WR)+ref(WT))/(ref(WT)+ref(rout)-ref(rstep))"
)
WT  real_variable
(
```

```
  value           : 2.0
)
circular_waveguide_section  circular_waveguide_section
(
  radius          : "ref(WR)" mm,
  length          : "ref(WL)" mm,
  conductivity    : 33000000.0 S/m
)
smooth_horn_section  smooth_walled_section
(
  profile         : ref(smooth_horn_section_profile),
  conductivity    : 33000000.0 S/m
)
smooth_horn_section_profile  linear_profile
(
  input_radius    : "ref(WR)" mm,
  output_radius   : "ref(istep)" mm,
  length          : "ref(lenc)" mm
)
smooth_horn_section_0001  smooth_walled_section
(
  profile         : ref(smooth_horn_section_profile_0001),
  conductivity    : 33000000.0 S/m
)
smooth_horn_section_profile_0001  linear_profile
(
  input_radius    : "ref(istep)" mm,
  output_radius   : "ref(rstep)" mm,
  length          : 0.1E+00 mm
)
smooth_horn_section_0002  smooth_walled_section
(
  profile         : ref(smooth_horn_section_profile_0002),
  conductivity    : 33000000.0 S/m
)
smooth_horn_section_profile_0002  linear_profile
(
  input_radius    : "ref(rstep)" mm,
  output_radius   : "ref(rout)" mm,
  length          : "ref(length)" mm
)
horn_bor_mesh  bor_mesh
(
  regions         : table
    (
    ),
  nodes           : table
    (
       1    0.00000E+00  "ref(rout)"
       2    0.00000E+00  "ref(rout)+ref(WT)"
       3  "-ref(leno)"  "ref(WR)+ref(WT)"
       4  "-ref(WL)-ref(length)-ref(lenc)"  "ref(WR)+ref(WT)"
       5  "-ref(WL)-ref(length)-ref(lenc)"  "ref(WR)"
    ),
  linear_segments  : table
    (
```

```
      1    1    2    0    0   0.00000E+00   0.00000E+00
      2    2    3    0    0   0.00000E+00   0.00000E+00
      3    3    4    0    0   0.00000E+00   0.00000E+00
      4    4    5    0    0   0.00000E+00   0.00000E+00
   ),
  cubic_segments   : table
   (
   ),
  length_unit      : mm
)
 Added from SPZLENS output
ZLOFF  real_variable
(
  value           : -3.2
)

horn_bor_mesh_lens  bor_mesh
(
  regions         : table
   (
      1   2.55000E+00   1.00000E+00   0.00000E+00
   ),
  nodes           : table
   (
      1  "ref(ZLOFF)+6.0068e+02"   0.00000E+00
      2  "ref(ZLOFF)+6.0053e+02"   3.89850E+01
            .
            .
            .
     93  "ref(ZLOFF)+4.5909e+02"   3.03370E+02
   ),
  linear_segments  : table
   (
      1    1    2    0    1  -1.00000E+00   0.00000E+00
      2    2    3    0    1  -1.00000E+00   0.00000E+00
            .
            .
            .
      8    8   93    0    1  -1.00000E+00   0.00000E+00
   ),
  cubic_segments   : table
   (
      1    9   10   11   12    0    1  -1.00000E+00   0.00000E+00
      2   12   13   14   15    0    1  -1.00000E+00   0.00000E+00
            .
            .
            .
     28   90   91   92   93    0    1  -1.00000E+00   0.00000E+00
   ),
  length_unit      : mm
)

TX_wide  corrugated_horn_mode_matching
(
  frequency       : ref(TX_wide_freq),
  horn            : ref(horn),
```

```
  output_file_name : TX_wide/reflections.edx,
  coef_file_name   : TX_wide/reflections.dat
)

TX_wide_freq  frequency_range
(
  frequency_range  : struct(start_frequency: 9.0 GHz, end_frequency: 11.0 GHz, number_of_frequencies: 41)
)

TX_cent  corrugated_horn_mode_matching
(
  frequency        : ref(TX_cent_freq),
  horn             : ref(horn),
  output_file_name : " ",
  coef_file_name   : " "
)

TX_cent_freq  frequency_range
(
  frequency_range  : struct(start_frequency: 10.0 GHz, end_frequency: 10.0 GHz, number_of_frequencies: 1)
)

optimiser  optimisation_manager
(
  variables        : ref(optimiser_0001),
  goals            : sequence(ref(optimisation_goals_radiation_pattern)),
  max_iterations   : 30
)

optimiser_0001  optimisation_variables
(
  real_variables   : sequence
    (    struct(variable_object: ref(length), min: 80.0, max: 500.0),
    struct(variable_object: ref(rout), min: 20.0, max: 150.0)
    )
)

optimisation_goals_radiation_pattern  optimisation_goals_radiation_pattern
(
  source           : ref(TX_cent),
  goals_on_axis_directivity : sequence
    (    struct(frequency_index: -1.0, goal: 14.5, weight: 1.0, action: target)
    ),
  goals_cross_polar : sequence
    (    struct(frequency_index: -1.0, theta_min: 0.0, theta_max: 60.0, goal: -30.0, weight: 1.0, action:
minimise)
    )
)

//DO NOT MODIFY OBJECTS BELOW THIS LINE.
//THESE OBJECTS ARE CREATED AND MANAGED BY THE
//GRAPHICAL USER INTERFACE AND SHOULD NOT BE
//MODIFIED MANUALLY!
view  view
(
  objects          : sequence(ref(view_horn_section_plot)),
```

```
  dimension        : 2D
)

view_horn_section_plot  horn_section_plot
(
)

 //$$ Saved at 11:29:17 on 11.12.2013 by CHAMP ver. 3.0.0 SN=003001
```